PVT SIMULATORS FOR MICROCOMPUTERS

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DEDICATION

I would like to dedicate this report to my mother and father. They have patiently provided me with love and support throughout my life.

PVT SIMULATORS FOR MICROCOMPUTERS

BY

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REPORT

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Kamaruddin Salleh developed the PVT simulator programs used in this study. These programs had excellent logic. Because of his superb work, very few logic modifications were made in redesigning his programs for implementation on microcomputers.

ABSTRACT

Fluid analysis or pressure-volume-temperature (PVT) analysis of petroleum fluids can be obtained by either laboratory analysis, empirical correlations, or through the use of equations of state. Laboratory analysis is notably accurate but is expensive, time-consuming, and requires specialized equipment and personnel. Empirical correlations are readily available and easy to use but can have inherent inaccuracies because conditions vary from those in which the correlations were developed. Fluid analysis by simulation technique using equations of state requires complex computer calculations, which until recent advances in microcomputer technology, could only be performed on mainframe computers which were capable of handling the tedious calculations and large data storage.

PVT simulators have been written on mainframe computers, but few have been adapted to the microcomputer, leaving the engineer with the option of costly laboratory analysis, inconvient timesharing, or less precise empirical correlation. The purpose of this report was to modify a PVT simulator written for a mainframe computer to run on a microcomputer.

PVTBO, PVTVO, and PVTGC are a set of petroleum fluid analysis programs which have been adapted to run on an IBM-PC

microcomputer. The programs provide PVT properties of a black oil, a volatile oil, and a gas condensate system, respectively, based on the Peng-Robinson equation of state. The programs can run on an IBM-PC microcomputer with at least 192K memory.

Input requirements are pressure, temperature, and overall fluid composition. The outputs for the black oil and volatile oil system include phase compostions, solution gas-oil ratios, formation volume factors, oil densities, gas gravities, relative volumes, and oil and gas viscosities. In addition, the volatile oil system includes percent liquid and gas produced, and equivalent liquid recovery. The outputs for the gas condensate system include phase compostions, condensate liquid volumes, percent gas produced, relative volumes, gas formation factors, gas viscosities, equivalent liquid recoveries.

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CHAPTER 1

INTRODUCTION

1.1 The Need for Fluid Analysis

Pressure-volume-temperature (PVT) analysis enables the engineer to relate surface production to reservoir withdrawal. Specifically, it provides the production engineer with infromation needed to optimize separator yields. For the reservoir engineer, reliable PVT properties are indispensable for volumetric and material balance approaches to reserve determination.

1.2 Obtaining PVT Data

Before computers became widespread, PVT data had to be obtained either by laboratory analysis or by empirical correlation. Laboratory analysis is notably accurate but is expensive, time-consuming, and requires specialized equipment and personnel. Empirical correlations are readily available and easy to use but can have inherent inaccuracies because conditions and locations vary from that in which the correlations were developed. Fluid analysis by simulation requires repitition of long, complex, and laborious calculations which were inconceivable until the advent of the computer. Today with computer PVT simulation, accuracy can be obtain approaching that of laboratory analysis.

1.3 Modifying PVT Simulators for Microcomputers

PVT simulators have been written on mainframe computers, but few have been adapted to the microcomputer. Mainframe computers used by large companies, while being fast, may often be tied up with the company's accounting and seismic processing. Smaller companies have had to rely on inconvient and expensive timesharing for their PVT computer simulation.

From the late 1970's until the present (1986), we have seen a rapid growth in microcomputer technology. Along with the growth in technology has been a reduction in costs, thus enabling the petroleum engineer to have a stand-alone personal computer dedicated to specific tasks. This report makes use of the new microcomputer technology and modifies a PVT computer simulator written for a mainframe computer for use on a microcomputer. The objective of this study was to make use of new microcomputer technology and modify PVT simulators, written for a mainframe computer, for use on an IBM-PC microcomputer.

1.4 Input Requirements

The programs in this study use fluid composition as the basis for calculating PVT properties. Compositional analysis is obtained by gas chromatography. The fluid composition is entered as

mole fractions. In addition, the molecular weight and the specific gravity of the heavy-plus fraction are required. With the desired reservoir temperature and pressure, the input data are used to compute PVT data based on the Peng-Robinson equation of state. As an option, the user can input the experimental bubble point pressure. Selecting this option, the program will try to match the experimental bubble point pressure by varying the methane heptane-plus interaction coefficients until a match is made. This procedure provides for a more representative and accurate simulation. However, part of the laboratory analysis this program proposes to eliminate is required to obtain the experimental bubble point pressure. Futher details of this option is discussed in Logic of Program and Flow Charts, Chapter 3.

1.5 Output

The outputs for the black oil and volatile oil system include phase compostions, solution gas-oil ratios, formation volume factors, oil densities, gas gravities, relative volumes, and oil and gas viscosities. In addition, the volatile oil system includes percent liquid and gas produced, and equivalent liquid recovery. The outputs for the gas condensate system include phase compostions, condensate liquid volumes, percent gas produced, relative volumes, gas formation factors, gas viscosities, equivalent liquid recoveries.

1.6 Collection of Reservoir Fluid Samples

Samples of the reservoir fluid should be collected at an early stage in the reservoir's producing life, in order to have samples that are representative of the original reservoir fluid. There are basically two ways of collecting such samples, either by direct subsurface sampling or by surface recombination of the oil and gas phases.

1.6.1 Subsurface Sampling (Well-stream)

A subsurface sample is obtained by running a sampling bomb in the hole on a wireline. The bomb is lowered to the reservoir depth and the sample is collected from the subsurface well stream at the bottom hole pressure. The sample is genuinely representative when the bottom hole flowing pressure is above the bubble point pressure. When sampling a gas saturated reservoir or one in which bottom hole flowing pressures fall below the bubble point, problems can arise since liquid and gas flow rates are almost always different. These problems can be overcome by well conditioning prior to sampling. The procedure of well conditioning calls for production at a low stabilized rate followed by a shut in period. The sample is then taken while the well is shut in or at a very low flow rate. This

procedure allows for the undisolved gas to redissolve in the proper proportion.

1.6.2 Surface Recombination Sampling

A surface sample is obtained by collecting separate volumes of oil and gas at separator conditions and recombining according to the gas oil ratio to give a composite fluid sample. The samples should be taken while the well is under steady state flow conditions so that the fluid compositions are the same at the well head as they are at the bottom of the tubing. As with the subsurface sampling method, the surface recombination method will only provide the correct gas oil ratio if the pressure near the well bore is at or above the bubble point pressure. The advantage of surface recombination sampling is that it enables the collection of large fluid samples which can be statistically averaged over a period of several hours, giving a more reliable value of the producing gas oil ratio. The disadvantage is that field measurements are more prone to error. An error of five per cent in the gas oil ratio measurement could cause a 100 to 200 psi error in the bubble point pressure of the recombined fluid. Therefore the subsurface sampling method is superior when an accurate measure of the bubble point pressure of an undersaturated reservoir fluid is desired.

1.7 Organization of the Report

If you are only interested in using the program, you can procede directly to Chapter 5 Using the Program. Although the program is user friendly, it is essential to understand the input conventions before attempting to use the program.

In addition a review of the chemical thermodynamics and technical equations used is presented in Chapter 2. A presentation of program logic is outlined in Chapter 3. Comparison of the computed data with laboratory data along with a summary of deviations from experimental data is presented in Chapter 4. The program source codes are listed in Appendix A, B, and C.

CHAPTER 2

MODEL EQUATIONS

2.1 Equation of State

The Peng-Robinson equation of state[1] is chosen for this program because of its simplicity and accuracy in calculating vapor pressures and equilibrium ratios. The equation shows its greatest advantages in the prediction of liquid phase densities.

The Peng-Robinson equation of state is represented by the following equation:

$$P = \frac{RT}{v - b} - \frac{a(T)}{v(v + b) + b(v - b)} \qquad (2\text{-}1)$$

It is a semiempirical equation of state that expresses pressure as the sum of two terms, a repulsive pressure P_R and an attractive pressure P_A as follows: $P = P_R + P_A$. The equations of van der Waals[2], Redlich and Kwong[3], and Soave[4] are all examples of an equation of state of this type. All of these equations including the Peng-Robinson have the repulsion pressure expressed by the van der Waals hard sphere equation, that is:

$$P_R = \frac{R\,T}{v - b} \qquad (2\text{-}2)$$

The attraction pressure is expressed by

$$P_A = - \frac{a}{g(v)} \qquad (2\text{-}3)$$

where g(v) is a function of molar volume v and the constant b which is related to the size of hard spheres. The parameter a is a measure of the intermolecular attraction force.

The Peng-Robinson equation of state can be rewritten as a cubic equation in terms of Z as follows:

$$Z^3 - (1 - B)\,Z^2 + (A - 3B^2 - 2B)\,Z - (A\,B - B^2 - B^3) = 0 \qquad (2\text{-}4)$$

where

$$A = \frac{a\,T}{R^2\,T^2} \qquad (2\text{-}5)$$

$$B = \frac{b\,P}{R\,T} \qquad (2\text{-}6)$$

$$Z = \frac{P\,v}{R\,T} \tag{2-7}$$

Solving equation (2-1) at the critical point gives:

$$a(T_c) = \frac{0.45724\,R^2\,T_c^2}{P_c} \tag{2-8}$$

$$b(T_c) = \frac{0.07780\,R\,T_c}{P_c} \tag{2-9}$$

$$Z_c = 0.307 \tag{2-10}$$

At temperatures and pressures other than the critical:

$$a(T) = a(T_c)\ \alpha(T_r,\omega) \tag{2-11}$$

$$b(T) = b(T_c) \tag{2-12}$$

where

$$\alpha(T_r,\omega) = [1 + \kappa(1 - T_r^{1/2})]^2 \tag{2-13}$$

$$\kappa = 0.37464 + 1.54226\ \omega - 0.26992\ \omega^2 \tag{2-14}$$

Applying the thermodynamic relationship

$$\ln \frac{f}{p} = \int_0^P (v/RT - 1/P)\, dP \qquad (2\text{-}15)$$

to equation (2-1) gives the following expression for fugacity coefficient

$$\ln \frac{f}{p} = Z - 1 - \ln(z - B) - \frac{A}{2\sqrt{2}\,B} \ln\left(\frac{Z + 2.414\,B}{Z - 0.414\,B}\right) \qquad (2\text{-}16)$$

The fugacity coefficient for each component i in a mixture is calculated from the following equation

$$\ln \frac{f_i}{x_i P} = \frac{b_j}{b} (Z - 1) - \ln(Z-B) - \frac{A}{2\sqrt{2}\,B} X$$

$$\left(\frac{2 \sum_i X_i a_{ij}}{a} - \frac{b_i}{b}\right) \ln \left(\frac{Z + 2.414\,B}{Z - 0.414\,B}\right) \qquad (2\text{-}17)$$

The mixing parameters are given by

$$a = \sum_i \sum_j x_i x_j a_{ij} \qquad (2\text{-}18)$$

$$b = \sum_i x_i b_i \qquad (2\text{-}19)$$

where

$$a_{ij} = (1 - d_{ij})\, a_i^{1/2}\, a_j^{1/2} \qquad (2\text{-}20)$$

In equation (2-20) d_{ij} is an empirically determined binary interaction coefficient.

Equations (2-4) is a cubic equation of state having one root for single phase systems and three roots for two phase systems. In the two phase region the largest root corresponds to the compressibility factor of the vapor while the smallest root corresponds to the compressibility factor of the liquid.

2.2 Flash Vaporization

A material balance on the i^{th} component in equilibrium results in:

$$z_i n = x_i n_l + y_i n_g \qquad (2\text{-}21)$$

where n = total number of moles in the mixture

n_l = total number of moles in the liquid

n_g = total number of moles in the gas

z_i = mole fraction of the i^{th} component in the total mixture

x_i = mole fraction of the i^{th} component in the liquid

y_i = mole fraction of the i^{th} component in the gas

The distribution of a component of a system between vapor and liquid is expressed by the equilibrium ratio K, defined as:

$$K_i = \frac{y_i}{x_i} \tag{2-22}$$

Solving K_i for y_i gives $y_i = x_i K_i$. Substituting this into equation (2-21) and rearranging gives an equation for x_i as follows:

$$x_i = \frac{z_i n}{n_l + n_g K_i} \tag{2-23}$$

A similar equation can be derived for y_i:

$$y_i = \frac{z_i n}{n_g + n_l / K_i} \tag{2-24}$$

At equilibrium, the mole fractions of the components in both liquid and vapor phase must sum to to unity. For simplicity, we assume a total mixture of one mole so that $n_l + n_g = 1 = n$. Thus equations (2-23) and and (2-24) can be refined to:

$$\sum_i x_i = \sum_i \frac{z_i}{1 + n_g(K_i - 1)} = 1 \qquad (2\text{-}25)$$

$$\sum_i y_i = \sum_i \frac{z_i K_i}{1 + n_g(K_i - 1)} = 1 \qquad (2\text{-}26)$$

Since $\sum_i y_i - \sum_i x_i = 0$, the following condensed equation can be solved for gas mole fraction by a method of trial and error:

$$F(n_g) = \sum_i \frac{z_i (K_i - 1)}{1 + n_g (K_j - 1)} = 0 \qquad (2\text{-}27)$$

The trial and error method used to solve equation (2-27) is Brent's version of an algorithm called Zeroin[5]. The algorithm combines the certainty of bisection with the ultimate speed of linear interpolation and inverse quadratic interpolation methods.

2.3 Differential Vaporization

A material balance on the i^{th} component of a mixture in equilibrium after a differential amount of vaporization is given by:

$$y_i\, dn_l = x_i\, n_l - (x_i - dx_i)(n_l - dn_l) \qquad (2\text{-}28)$$

where dx_i = the change in the mole fraction of the i^{th} component caused by the loss of an increment of vapor and

dn_l = number of moles of gas formed during the incremental vaporization

Expanding equation (2-28) gives:

$$y_i\, dn_l = x_i\, dn_l + n_l\, dx_i - dx_i\, dn_l \qquad (2\text{-}29)$$

If dx_i and dn_l is small, the term $dx_i\, dn_l$ can be negelected. Also $K_i\, x_i$ can be substituted for y_i to give:

$$K_i\, x_i\, dn_l = n_l\, dx_i + x_i\, dn_l \qquad (2\text{-}30)$$

or

$$\frac{dn_l}{n_l} = \frac{1}{K_j - 1}\,\frac{dx_j}{x_j} \qquad (2\text{-}31)$$

If it can be assumed that the values of K_i remain constant for a resonable change in pressure, equation (2-31) can be integrated as follows:

$$\int_{n_{li}}^{n_{lf}} \frac{dn_i}{n_l} = \frac{1}{Ki - 1} \int_{x_{ii}}^{x_{if}} \frac{dx_i}{x_i} \qquad (2\text{-}32)$$

$$\ln \frac{n_{lf}}{n_{li}} = \frac{1}{K_i - 1} \ln \frac{x_{if}}{x_{ii}} \qquad (2\text{-}33)$$

where the second subscripts i and f indicate initial and final conditions.

Modifying equation (2-33) by replacing x_{if} with y_{if}/K_i and rearranging gives:

$$y_{if} = K_i x_{ii} \left(\frac{n_{lf}}{n_{li}}\right)^{K_j - 1} \qquad (2\text{-}34)$$

Since $\sum_i x_{if} = 1$ and $\sum_i y_{if} = 1$, it follows that:

$$\sum_i x_{if} = \sum_i x_{ii} \left(\frac{n_{lf}}{n_{li}}\right)^{K_j - 1} = 1 \qquad (2\text{-}35)$$

and

$$\sum_i y_{if} = \sum_i K_i x_{ii} \left(\frac{n_{lf}}{n_{li}}\right)^{Kj-1} = 1 \qquad (2\text{-}36)$$

Combining these two equations yields:

$$F\left(\frac{n_{lf}}{n_{li}}\right) = \sum_i y_{if} - \sum_i x_{if} = \sum_i (K_i - 1)\, x_{ii} \left(\frac{n_{lf}}{n_{li}}\right)^{K_j - 1} = 0 \qquad (2\text{-}37)$$

Differentiation of equation (2-37) with respect to n_{lf}/n_{li} gives:

$$\frac{dF}{d(n_{lf}/n_{li})} = \sum_i (K_i - 1)^2 \; x_{ii} \; (n_{lf}/n_{li})^{Ki-2} \qquad (2\text{-}38)$$

Equation (2-37) and (2-38) are used to solve for n_{lf}/n_{li} by the Newton-Raphson method[6].

2.4 Correlations Used in the Program

2.4.1 Correlations for Binary Interaction Parameters

The Grabowski-Daubert[7] and Lawal[8] correlations are used in this program to estimate binary interaction parameters.

The relationships for the Grabowski-Daubert correlation are given as follows:

$$k_{il} = 0.1294 + 0.0292\ (|d_i - d_l|) - 0.0222\ (d_i - d_l)^2 \qquad (2\text{-}39)$$

$$k_{im} = -0.0836 + 0.1055\ (|d_i - d_m|) - 0.01\ (d_i - d_m)^2 \qquad (2\text{-}40)$$

$$k_{in} = 0.0178 + 0.0244\ (|d_i - d_n|) \qquad (2\text{-}41)$$

where

k_{il} = binary interaction parameters of hydrocarbon-CO_2 pairs

k_{im}= binary interaction parameters of hydrocarbon-N_2 pairs

k_{in}= binary interaction parameters of hydrocarbon-H_2S pairs

d_i = hydrocarbon solubility parameter

d_l = CO_2 solubility parameter

d_m = N_2 solubility parameter

d_n = H_2S solubility parameter

The relationship for the Lawal correlation is as follows:

$$k_{ij} = \frac{\ln ((|MW_i - MW_j|) + 1)^n}{T_{bi}/1.8} \qquad (2\text{-}42)$$

where

n = 0.92 for hydrocarbon pairs (i being the lighter component)

n = 1.6 for hydrocarbon - N_2 or N_2 - CO_2 pairs

n = 2.5 for hydrocarbon - CO_2 pairs

2.4.2 Correlation Used for Heavy-Plus Critical Property Estimation

The Kessler-Lee correlation[6] for molecular weight is given by the following expression:

$$MW + 12272.6 - 9486.4\ SG - (4.6523 - 3.3287\ SG)\ T_b - (1 - 0.77084\ SG - 0.02058\ SG^2)\ (1.3437 - 720.79/T_b)107/T_b - (1 - 0.80882\ SG + 0.02226\ SG^2)\ (1..8828 + 181.98/T_b)\ 1012/Tb^3 = 0 \qquad (2\text{-}43)$$

where

MW = molecular weight of heavy-plus

SG = specific gravvity of heavy-plus

T_b = normal boiling point temperature

Differenting equation (2-43) with respect to T_b gives the following expression:

$$dF/dT_b =$$

$$-4.6523 + 3.3287\ SG + (1.3437 - 1.0358\ SG - 0.027653\ SG^2)10^7/T_b^2 - (1441.58 - 1111.23\ SG - 29.6677\ SG^2)10^7/T_b^3 + 5.6484 - 4.5685\ SG + 0.12573\ SG^2)10^{12}/T_b^4 - (727.92 - 588.756\ SG + 16.2035\ SG^2)10^{12}/T_b^5 \qquad (2\text{-}44)$$

With the molecular weight (MW) and the specific gravity (SG) of the heavy-plus fraction, equations (2-43) and (2-44) are used to calculate the normal boiling point temperature (T_b) using a Newton-Raphson[6] iteration.

The calculated normal boiling point temperature is used, along with the given molecular weight and specific gravity, to determine the critical temperature (T_c), the critical pressure (P_c), and the acentric factor of the heavy-plus. The following equations from the Kessler-Lee correlation are used:

$$T_c = 341.7 + 811\ SG + (0.4244 + 0.1174\ SG)\ T_b + (0.4669 - 3.2623\ SG)\ 10^5/T_b \quad \ln P_c = 8.3634 - 0.0566/SG - (0.24244 + 2.2898/SG + 0.11857/SG^2)10^{-3} T_b + (1.4685 + 3.648/SG + 0.47227/SG^2)10^{-7}T_b^2 - (0.42019 + 1.6977/SG^2)10^{-10}T_b^3 \qquad (2\text{-}45)$$

$$\omega = [\ln (14.7/P_c) - 5.92714 + 6.0948/T_{br} + 1.28862 \ln T_{br} - 0.169347\ T_{br}^6\ ] / [\ 15.2518 - 15.6875/T_{br} - 13.4721 \ln T_{br} + 0.43577\ T_{br}^6\ ] \quad \text{when } T_{br} < 0.8 \qquad (2\text{-}46)$$

or

$$\omega = 7.904 + 0.1352\ K_w - 0.007465\ K_w^2 + 8.359\ T_{br} + (1.408 - 0.01063\ K_w)/T_{br} \quad \text{when } T_{br} > 0.8 \qquad (2\text{-}47)$$

where

$$T_{br} = T_b/T_c$$

$$K_w = (T_b)^{1/3}/SG$$

2.4.3 Correlation for Calculating Dew Point Pressure

The Nemeth-Kennedy correlation[10] is used to calculate the upper dew point pressure P_d and is given by the following expression:

$$\ln P_d = A_1 [Z_{C2} + Z_{CO2} + Z_{H2S} + Z_{C6} + 2(Z_{C3} + Z_{C4}) + Z_{C5} + 0.4Z_{C1} + 0.2Z_{N2}] + A_2 SG_{H+} + A_3 [Z_{C1}/(Z_{H+} + 0.002)] + A_4 T + A_5(Z_{CH+} \times MW_{H+}) + A_6(Z_{H+} \times MW_{H+})^2 + A_7(Z_{H+} \times MW_{H+})^3 + A_8 [MW_{H+}/(SG_{H+} + 0.0001)] + A_9 [MW_{H+}/(SG_{H+} + 0.0001)]^2 + A_{10} [MW_{H+}/(SG_{H+} + 0.0001)]^3 + A_{11} \quad (2\text{-}48)$$

where

$A_1 = -2.0623045$

$A_2 = 6.6259728$

$A_3 = -4.4670559 \times 10^{-3}$

$A_4 = 1.0448346 \times 10^{-4}$

$A_5 = 3.2673714 \times 10^{-2}$

$A_6 = -3.6453277 \times 10^{-3}$

$A_7 = 7.4299951 \times 10^{-5}$

$A_8 = -1.1381195 \times 10^{-1}$

$A_9 = 6.2476497 \times 10^{-4}$

$A_{10} = -1.0716866 \times 10^{-6}$

$A_{11} = 1.0746622 \times 10$

2.4.4 Correlation for Oil Viscosity

The Beggs-Robinson correlation[11] is used to calculate the oil viscosity μ_o. The relationship is given as follows:

$$\mu_o = R_4 \mu_{oD} R_5 \qquad (2\text{-}49)$$

where

$$R_5 = 5.44 (R_s + 150)^{-0.338}$$

$$R_4 = 10.715 (R_s + 100)^{-0.515}$$

$$\mu_{oD} = 10^{R3} - 1$$

$$R_3 = R_2 T^{-1.163}$$

$$R_2 = 10^{R1}$$

$$R_1 = 3.0324 - 0.02023 API_{oD}$$

API_{oD} = dead oil API gravity

T = temperature (°F)

2.4.5 Correlation for Gas Viscosity

The Lee-Eakin correlation[12] is used to calculate the gas viscosity μ_v. The relationship is given as follows:

$$\mu_v = K \exp(X \rho_s^G)/1000 \qquad (2\text{-}50)$$

where

$$\rho_s = 0.43264 \, GG \, P/(Z_v T)$$

$$G = 2.4 - 0.2X$$

$$X = 3.5 + 986/T + 0.2897 \, GG$$

$$K = (9.4 + 0.58 \, GG) \, T^{1.5} / (209 + 551GG + T)$$

T = temperature (°R)

GG = gas gravity (air = 1)

2.5 Equations Used to Calculate PVT Proverties

Differential vaporization calculations are performed on the black oil, volatile oil, and gas condensate systems. Flash vaporization calculations are performed on black oil and volatile oil systems. PVT properties are obtained for both processes. The formulas used to determine these properties are as follows:

$$B_o = \frac{V_l \, n_l}{V_{lsc} \, n_{lsc}} \tag{2-51}$$

$$B_g = 0.0282 \, \frac{Z_v \, T}{P} \tag{2-52}$$

$$B_t = B_o + (R_{si} - R_s) \, \frac{B_g}{5.615} \tag{2-53}$$

$$\rho_o = \Sigma_j \, \frac{(MW_j \, x_j)}{V_l} \tag{2-54}$$

$$R_s = \frac{2130 \, (n_{vsc} - n_v)}{V_{lsc} \, n_{lsc}} \tag{2-55}$$

$$RV = \frac{V_l n_l + V_v n_v}{v_{li} n_{li}} \qquad (2\text{-}56)$$

where

B_o = Oil formation volume factor (BB/STB)

B_g = Gas formation volume factor (cu. ft/SCF)

B_t = Total formation volume factor (RB/STB)

ρ_o = Oil density (lb/cu. ft)

R_s = Solution gas-oil ratio (SCF/STB)

R_{si} = Solution gas-oil ratio at initial conditions (SCF/STB)

RV = Relative Volume

n_l = liquid mole fraction at given pressure

n_v = gas mole fraction at given pressure

n_{vsc} = gas mole fraction at standard conditions

V_l = Liquid volume at given pressure (cu. ft)

V_{lsc} =Liquid volume at standard conditions (SCF)

V_v = Gas volume at given pressure (cu. ft)

n_{lsc} = Liquid mole fraction at standard conditions

Subscript j denotes the component, while subscript i denotes initial conditions.at saturation pressure.

2.6 Constant Volume Depletion Equations

Constant volume depletion are performed on volatile oil and gas condensate systems. The results are used in the calculation of equivalent liquid recovery during depletion. Constant volume depletion assumes a constant reservoir volume. In this program that volume is assumed to be 100 cu. ft (for convenience) at every pressure stage. When the fluid is a volatile oil system, the initial conditions are at the bubble point pressure, whereas the gas condensate system has its initial condition at its upper dew point pressure. The properties obtained and their fomulas are:

$$GP = \frac{1000\,[TML_i - TML - TMG]}{TML_i} \qquad (2\text{-}57)$$

$$ELC_j = 19.715\ MV_j\ y_j \qquad (2\text{-}58)$$

$$PP = ELC_j\ GP \qquad (2\text{-}59)$$

where

GP = gas phase produced (percent volume)

TML = total moles ol liquid remaining

TMG = total moles of gas remaining

ELC_j = equivalent liquid content of component i (GPM)

MV_i = molar volume of component i (cu. ft/lb-mole)

PP_i = plant products in gas phase of component i (gallons)

Subscript i denotes initial condition as stated above.

CHAPTER 3

LOGIC OF PROGRAM AND FLOW CHARTS

3.1 K-Value Calculation

Phase-equilibrium ratios, or K values as they are usually known, are used to compute the relative quantities and compositions of phases in equilibrium. The calculation of K values is iterative and consists of the following steps:

(1) Initial estimates of K-values are calculated using the correlation[13]:

$$K_i = \frac{\exp\left[\, 5.37\,(1+\omega_i)\,(1-T_{ci}/T)\,\right] P_{ci}}{P} \qquad (3\text{-}2)$$

(2) Using the most recently estimated K-values, perform flash or differential vaporization calculation (see detailed section on flash and differential vaporization calculations) to determine the liquid and vapor mole fractions.

(3a) Using liquid mole fractions of each component, calculate $A_{(liquid)}$ and $B_{(liquid)}$ for calculation of a new liquid compressibility factor using equation (2-2).

(3b) Using vapor mole fractions of each component, calculate $A_{(vapor)}$ and $B_{(vapor)}$ for calculation of a new vapor compressibility factor using equation (2-2).

(4a) Use the liquid compressibility factor to calculate the liquid fugacities.

(4b) Use the vapor compressibility factor to calculate the vapor fugacities.

(5) Calculate a new improved set of K-values by:

$$K_i^{(k+1)} = K_i^{(k)} \exp [\, \lambda^{(k)} g_j^{(k+1)}] \qquad (3\text{-}3)$$

where $$g_j = \ln (f_{il}/f_{iv}) \qquad (3\text{-}4)$$

λ = acceleration parameter

The acceleration parameter is used only when the accelerated successive substitution option is chosen, otherwise it is set equal to 1.

(6) Test for convergence of K-values by using

$$\Sigma_j \frac{[K_i^{(k+1)} - K_i^{(k)}]^2}{K_i^{(k+1)}\ K_i} < 10^{-10} \qquad (3\text{-}5)$$

(7) Repeat steps (2) through (6) until convergence is obtained.

3.2 Fluid System Identification

The type of fluid can be identified by use of the summations $\sum_i Z_i K_i$ and $\sum_i Z_i/K_i$. Table 3.1 shows the possible computed combinations and fluid condition which exists for each.

Table 3.1

$\sum_i Z_i K_i$	$\sum_i Z_i/K_i$	Fluid Condition
1.0		bubble point
	1.0	upper dew point
> 1.0	> 1.0	two phase region
< 1.0	> 1.0	liquid phase (>bp)
> 1.0	< 1.0	vapor phase
< 1.0	< 1.0	computed error

3.3 Saturation Pressure Calculation

The saturation pressure is the bubble point pressure in a black oil or volatile oil system and the dew point pressure in a gas

condensate system. The calculation is acomplished by trial and error, using the value of $\sum_i Z_i K_i$ and $\sum_i Z_i/K_i$ to determine the fluid condition. The K-values are determined using the procedure of Section 3.1. The procedure for determining the bubble point is illustrated in Figure 3.1 and the procedure for determining the dew point pressure is illustrated in Figure 3.2.

Figure 3.1 Subroutine BUBPT

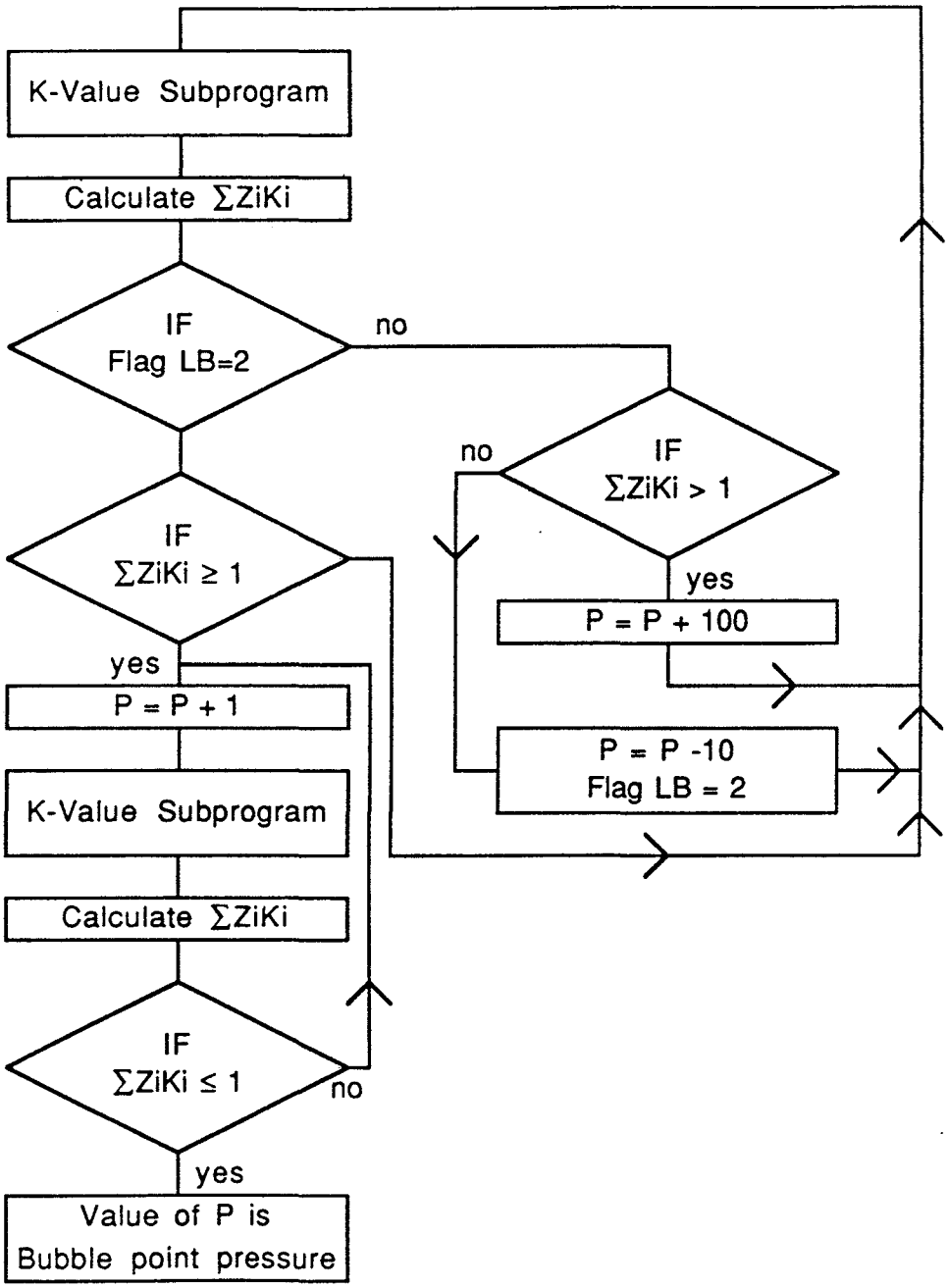
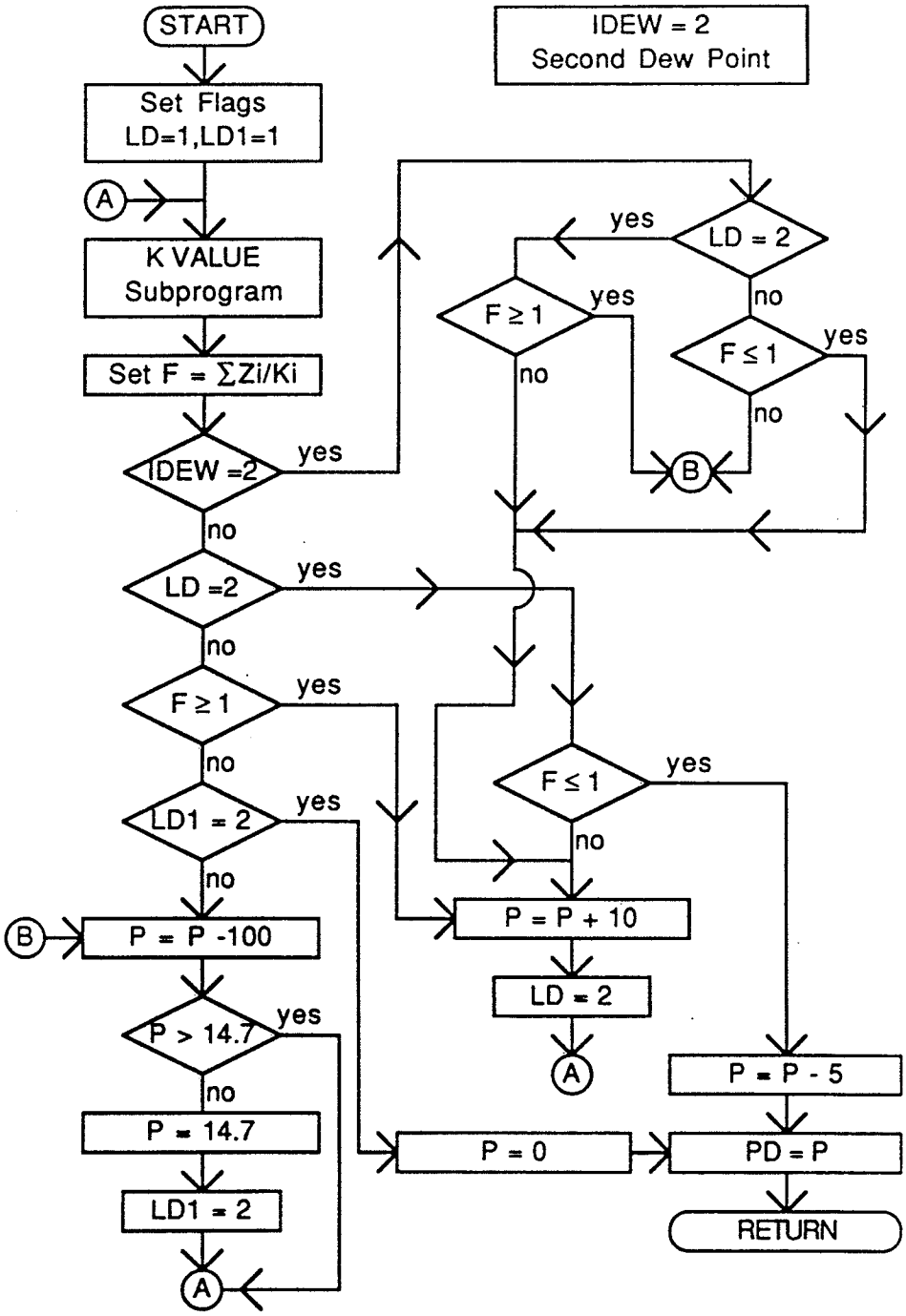


Figure 3.2 Subroutine DEWPT



CHAPTER 4

EXAMPLES WITH RESULTS AND ERROR ANALYSIS

4.1 Introduction

The outputs of two examples each of a typical black oil, volatile oil, and gas condensate system are presented and compared graphically and numerically with laboratory measured values of the examples. The examples are computed under the two different circumstances of either computing the saturation pressure or varying the interaction factors to match a given experimental saturation pressure. The gas-oil ratio, oil formation volume factor, oil density, oil viscosity, gas viscosity, and gas Z-factor are compared for the black oil and volatile oil samples. The properties of cumulative production, retrograde liquid volume, relative volume, and gas Z-factor are compared for the gas condensate samples.

The calculated results are numerically compared with the laboratory measured values by means of the absolute maximum percentage error (AMPE) and absolute average percentage error (AAPE). The AMPE and AAPE are calculated by the following equations:

$$AMPE = 100 \times \text{maximum} \left| (a_{cal} - a_{lab}) / a_{cal} \right|_i \qquad (4\text{-}1)$$

$$i = 1, 2, \cdots n$$

$$AAPE = 100 \times 1/n \sum_{1}^{n} \left| (a_{cal} - a_{lab}) / a_{lab} \right| \qquad (4\text{-}2)$$

where

a_{cal} = calculated value

a_{lab} = laboratory measured value

n = number of data points

The black oil, volatile oil, and gas condensate samples are presented in Section 4.2, 4.3, and 4.4 respectively.

4.2 Black Oil Examples

Black oil sample 1 had a laboratory measured bubble point pressure of 766.7 psia. The program calculated the bubble point pressure to be 719.7 psia, an error of 6.13%. Black oil sample 2 had a laboratory measured bubble point pressure of 1922.7 psia. The program calculated the bubble point pressure to be 1629.7 psia, an error of 15.24%.

In both samples the calculated PVT properties for flash vaporization gave smaller errors than those for differential vaporization, eventhough the experimental values were based on differential vaporization. Also, it should be noted that supplying the experimental bubble point pressure for matching, generally gave larger errors for most properties.

The output for the black oil samples are given in Tables 4.1, 4.2, 4.4, and 4.5. The results are presented graphically in Figures 4.1 through 4.12 and compared numerically in Tables 4.3 and 4.6.

Table 4.1 Black Oil Sample 1 Output

```
                ##########################
                # BLACK OIL PVT ANALYSIS #
                ##########################

ESTIMATED PROPERTIES OF HEAVY-PLUS ARE :

      NORMAL BOILING POINT TEMP. =  617.94  DEG.F
      CRITICAL TEMPERATURE =    944.58  DEG.F
      CRITICAL PRESSURE    =    240.45  PSIA
      ACENTRIC FACTOR      =    .7518

METHOD/CORRELATION USED          PURPOSE
-----------------------          -------
GRABOWSKI-DAUBERT                N2-H/C,CO2-H/C AND H2S-H/C BINARY
                                 INTERACTION PARAMETERS ESTIMATION
ACCD. SUCCESSIVE SUBSTITUTION    ITERATIVE ESTIMATION OF K-VALUES

INITIAL RESERVOIR CONDITIONS AND COMPOSITION (GIVEN)
----------------------------------------------------
RESERVOIR TEMPERATURE = 118.0   DEG.F
RESERVOIR PRESSURE    =  764.70  PSIA
BUBBLE POINT PRESSURE (EXPT.) = NOT GIVEN


COMPONENT                MOLE FRACTION
---------                -------------
N2                          .00210
H2S                         .04900
CO2                         .04000
METHANE                     .12970
ETHANE                      .07440
PROPANE                     .07800
I-BUTANE                    .01470
N-BUTANE                    .04150
I-PENTANE                   .01450
N-PENTANE                   .02580
HEXANES                     .03610
HEAVY+                      .49420

HEAVY-PLUS:MOLECULAR WEIGHT = 264.
           SPECIFIC GRAVITY =  .88530


CALC.BUBBLE POINT PRESSURE =     719.70  PSIA
```

Table 4.1 Continued

DIFFERENTIAL VAPORIZATION

PRES (PSIA)	TEMP (DEG.F)	SOLN GOR (SCF/STB)	OIL FVF (BBL/STB)	TOTAL FVF (BBL/STB)	DEG API	OIL DENSITY (GM/CC)	Z FACTOR	GAS FVF (CU.FT/SCF)	GAS GRAVITY (AIR=1)	OIL VISC (CP)	GAS VISC (CP)	RELATIVE VOLUME
719.7	118.0	209.2	1.156	1.1563	53.7	.7639	.000	.0000	.000	1.40	.0000	1.000
669.7	118.0	202.7	1.154	1.1781	53.6	.7645	.864	.0210	.823	1.42	.0123	1.019
619.7	118.0	189.9	1.149	1.2273	53.3	.7659	.870	.0229	.830	1.47	.0122	1.063
569.7	118.0	176.9	1.143	1.2877	52.9	.7672	.876	.0251	.837	1.52	.0120	1.116
519.7	118.0	163.6	1.138	1.3627	52.6	.7686	.883	.0277	.847	1.58	.0119	1.183
469.7	118.0	150.2	1.133	1.4570	52.3	.7700	.889	.0309	.859	1.65	.0117	1.266
419.7	118.0	136.4	1.127	1.5779	51.9	.7715	.896	.0348	.873	1.73	.0115	1.374
369.7	118.0	122.4	1.121	1.7364	51.6	.7730	.903	.0398	.891	1.81	.0114	1.514
319.7	118.0	108.1	1.115	1.9507	51.2	.7744	.911	.0464	.914	1.91	.0112	1.704
269.7	118.0	93.5	1.109	2.2529	50.9	.7760	.918	.0555	.942	2.02	.0110	1.972
219.7	118.0	78.2	1.102	2.7054	50.5	.7775	.926	.0687	.980	2.16	.0108	2.372
169.7	118.0	62.0	1.095	3.4472	50.1	.7791	.935	.0898	1.031	2.33	.0105	3.026
119.7	118.0	44.2	1.087	4.8603	49.7	.7807	.943	.1285	1.104	2.56	.0102	4.266
14.7	60.0	.0	1.000	37.6943	40.2	.8242	.987	.9850	1.311	3.42	.0083	32.841

FLASH VAPORIZATION

PRES (PSIA)	TEMP (DEG.F)	SOLN GOR (SCF/STB)	OIL FVF (BBL/STB)	TOTAL FVF (BBL/STB)	DEG API	OIL DENSITY (GM/CC)	Z FACTOR	GAS FVF (CU.FT/SCF)	GAS GRAVITY (AIR=1)	OIL VISC (CP)	GAS VISC (CP)	RELATIVE VOLUME
719.7	118.0	317.9	1.198	1.1980	53.7	.7639	.000	.0000	.000	1.28	.0000	1.000
669.7	118.0	311.0	1.195	1.2211	53.6	.7646	.864	.0210	.823	1.29	.0123	1.019
619.7	118.0	296.9	1.190	1.2752	53.2	.7660	.870	.0229	.830	1.33	.0121	1.062
569.7	118.0	282.2	1.184	1.3430	52.9	.7675	.876	.0251	.838	1.37	.0120	1.116
519.7	118.0	267.1	1.178	1.4284	52.5	.7690	.883	.0277	.848	1.42	.0119	1.183
469.7	118.0	251.2	1.171	1.5378	52.1	.7706	.890	.0309	.859	1.47	.0117	1.269
419.7	118.0	234.7	1.165	1.6807	51.7	.7723	.897	.0348	.872	1.53	.0115	1.380
369.7	118.0	217.3	1.157	1.8720	51.3	.7740	.905	.0399	.886	1.60	.0114	1.527
319.7	118.0	198.7	1.149	2.1372	50.9	.7758	.913	.0466	.903	1.68	.0112	1.727
269.7	118.0	178.6	1.141	2.5218	50.4	.7778	.922	.0557	.922	1.78	.0111	2.011
219.7	118.0	156.5	1.131	3.1158	49.9	.7800	.931	.0691	.946	1.91	.0109	2.436
169.7	118.0	131.6	1.119	4.1208	49.3	.7825	.941	.0904	.974	2.08	.0107	3.125
119.7	118.0	101.9	1.104	6.0909	48.6	.7855	.952	.1297	1.010	2.33	.0105	4.376
14.7	60.0	.0	1.000	56.9675	37.9	.8352	.991	.9807	1.153	4.22	.0088	47.699

Table 4.2 Black Oil Sample 1 Output with Experimental Bubble Point Given

```
                ##########################
                # BLACK OIL PVT ANALYSIS #
                ##########################

ESTIMATED PROPERTIES OF HEAVY-PLUS ARE :

      NORMAL BOILING POINT TEMP. =  617.94  DEG.F
      CRITICAL TEMPERATURE =    944.58  DEG.F
      CRITICAL PRESSURE    =    240.45  PSIA
      ACENTRIC FACTOR      =    .7518

METHOD/CORRELATION USED          PURPOSE
-----------------------          -------
GRABOWSKI-DAUBERT                N2-H/C,CO2-H/C AND H2S-H/C BINARY
                                 INTERACTION PARAMETERS ESTIMATION
ACCD. SUCCESSIVE SUBSTITUTION    ITERATIVE ESTIMATION OF K-VALUES

INITIAL RESERVOIR CONDITIONS AND COMPOSITION (GIVEN)
----------------------------------------------------
RESERVOIR TEMPERATURE = 118.0   DEG.F
RESERVOIR PRESSURE    =  764.70  PSIA
BUBBLE POINT PRESSURE (EXPT.) =    766.70  PSIA

COMPONENT                MOLE FRACTION
---------                -------------
N2                          .00210
H2S                         .04900
CO2                         .04000
METHANE                     .12970
ETHANE                      .07440
PROPANE                     .07800
I-BUTANE                    .01470
N-BUTANE                    .04150
I-PENTANE                   .01450
N-PENTANE                   .02580
HEXANES                     .03610
HEAVY+                      .49420

HEAVY-PLUS:MOLECULAR WEIGHT = 264.
           SPECIFIC GRAVITY =  .88530

CALC.BUBBLE POINT PRESSURE =     769.70  PSIA
```

Table 4.2 Continued

$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$ DIFFERENTIAL VAPORIZATION $
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

PRES (PSIA)	TEMP (DEG.F)	SOLN GOR (SCF/STB)	OIL FVF (BBL/STB)	TOTAL FVF (BBL/STB)	DEG API	OIL DENSITY (GM/CC)	Z FACTOR	GAS FVF (CU.FT/SCF)	GAS GRAVITY (AIR=1)	OIL VISC (CP)	GAS VISC (CP)	RELATIVE VOLUME
769.7	118.0	209.2	1.156	1.1560	53.7	.7641	.000	.0000	.000	1.40	.0000	1.000
719.7	118.0	203.3	1.154	1.1741	53.5	.7647	.858	.0194	.812	1.42	.0125	1.016
669.7	118.0	191.7	1.149	1.2149	53.2	.7659	.864	.0210	.818	1.46	.0123	1.052
619.7	118.0	179.8	1.144	1.2643	53.0	.7671	.870	.0229	.825	1.51	.0122	1.096
569.7	118.0	167.8	1.140	1.3245	52.7	.7684	.876	.0251	.834	1.56	.0120	1.149
519.7	118.0	155.6	1.133	1.3989	52.3	.7697	.883	.0277	.844	1.62	.0119	1.215
469.7	118.0	143.3	1.130	1.4922	52.0	.7710	.889	.0309	.857	1.69	.0117	1.298
419.7	118.0	130.7	1.125	1.6115	51.7	.7723	.896	.0348	.872	1.76	.0115	1.404
369.7	118.0	117.8	1.119	1.7675	51.4	.7736	.903	.0398	.891	1.84	.0114	1.543
319.7	118.0	104.7	1.114	1.9784	51.1	.7750	.911	.0464	.915	1.94	.0112	1.730
269.7	118.0	91.1	1.108	2.2757	50.8	.7764	.918	.0555	.945	2.04	.0110	1.994
219.7	118.0	76.9	1.102	2.7211	50.4	.7778	.926	.0687	.985	2.17	.0108	2.388
169.7	118.0	61.7	1.095	3.4523	50.1	.7792	.934	.0897	1.039	2.33	.0105	3.032
119.7	118.0	44.7	1.087	4.8492	49.7	.7808	.943	.1284	1.114	2.55	.0102	4.260
14.7	60.0	.0	1.000	37.7044	40.2	.8242	.987	.9850	1.311	3.42	.0083	32.859

$$$$$$$$$$$$$$$$$$$$$$$$
$ FLASH VAPORIZATION $
$$$$$$$$$$$$$$$$$$$$$$$$

PRES (PSIA)	TEMP (DEG.F)	SOLN GOR (SCF/STB)	OIL FVF (BBL/STB)	TOTAL FVF (BBL/STB)	DEG API	OIL DENSITY (GM/CC)	Z FACTOR	GAS FVF (CU.FT/SCF)	GAS GRAVITY (AIR=1)	OIL VISC (CP)	GAS VISC (CP)	RELATIVE VOLUME
989.7	118.0	326.8	1.204	1.2038	53.7	.7641	.000	.0000	.000	1.27	.0000	1.000
839.7	118.0	321.7	1.202	1.2168	53.6	.7646	.844	.0164	.803	1.29	.0128	1.010
789.7	118.0	310.9	1.198	1.2474	53.3	.7657	.850	.0175	.808	1.31	.0127	1.035
739.7	118.0	299.9	1.193	1.2839	53.0	.7668	.856	.0189	.814	1.34	.0125	1.064
689.7	118.0	288.5	1.189	1.3279	52.8	.7679	.862	.0204	.821	1.38	.0124	1.099
639.7	118.0	276.8	1.184	1.3813	52.5	.7691	.868	.0221	.829	1.41	.0122	1.142
589.7	118.0	264.7	1.179	1.4468	52.2	.7703	.874	.0242	.838	1.45	.0121	1.193
539.7	118.0	252.1	1.174	1.5281	51.9	.7715	.881	.0266	.848	1.49	.0119	1.257
489.7	118.0	239.0	1.169	1.6311	51.6	.7728	.888	.0295	.859	1.54	.0117	1.337
439.7	118.0	225.1	1.163	1.7639	51.3	.7742	.895	.0332	.872	1.59	.0116	1.440
389.7	118.0	210.4	1.157	1.9396	50.9	.7757	.902	.0377	.887	1.66	.0114	1.574
339.7	118.0	194.5	1.150	2.1794	50.6	.7772	.910	.0437	.904	1.73	.0113	1.754
289.7	118.0	177.1	1.142	2.5203	50.2	.7789	.918	.0517	.924	1.82	.0111	2.006
239.7	118.0	157.7	1.133	3.0326	49.7	.7808	.927	.0631	.947	1.93	.0109	2.375
189.7	118.0	135.6	1.123	3.8642	49.2	.7830	.937	.0805	.974	2.09	.0107	2.951
139.7	118.0	109.7	1.110	5.3849	48.6	.7856	.947	.1105	1.008	2.30	.0105	3.944
14.7	60.0	.0	1.000	38.5484	37.7	.8364	.991	.9886	1.170	4.32	.0087	48.785

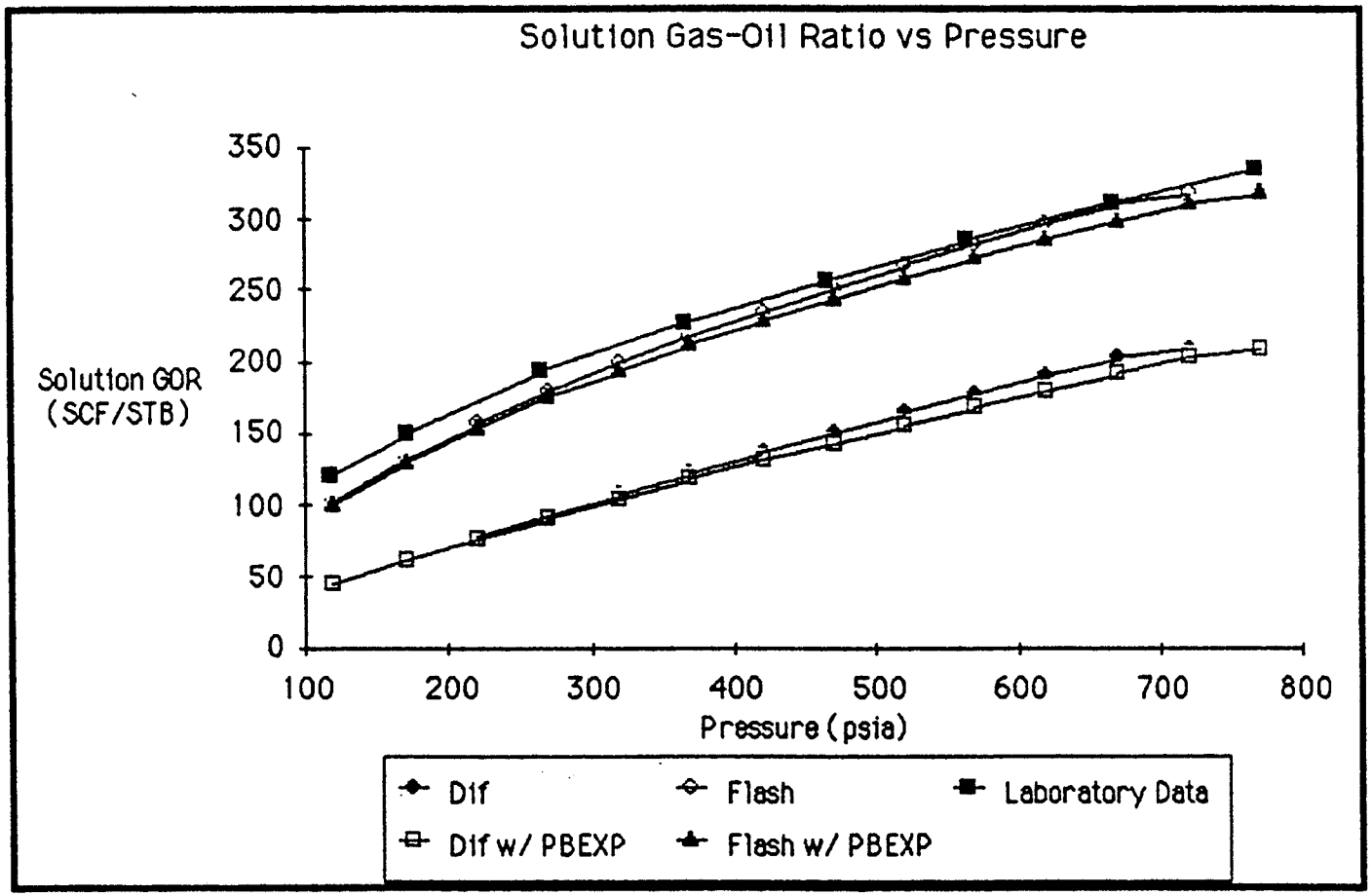


Figure 4.1 Black Oil Sample, 1 Gas-Oil Ratio

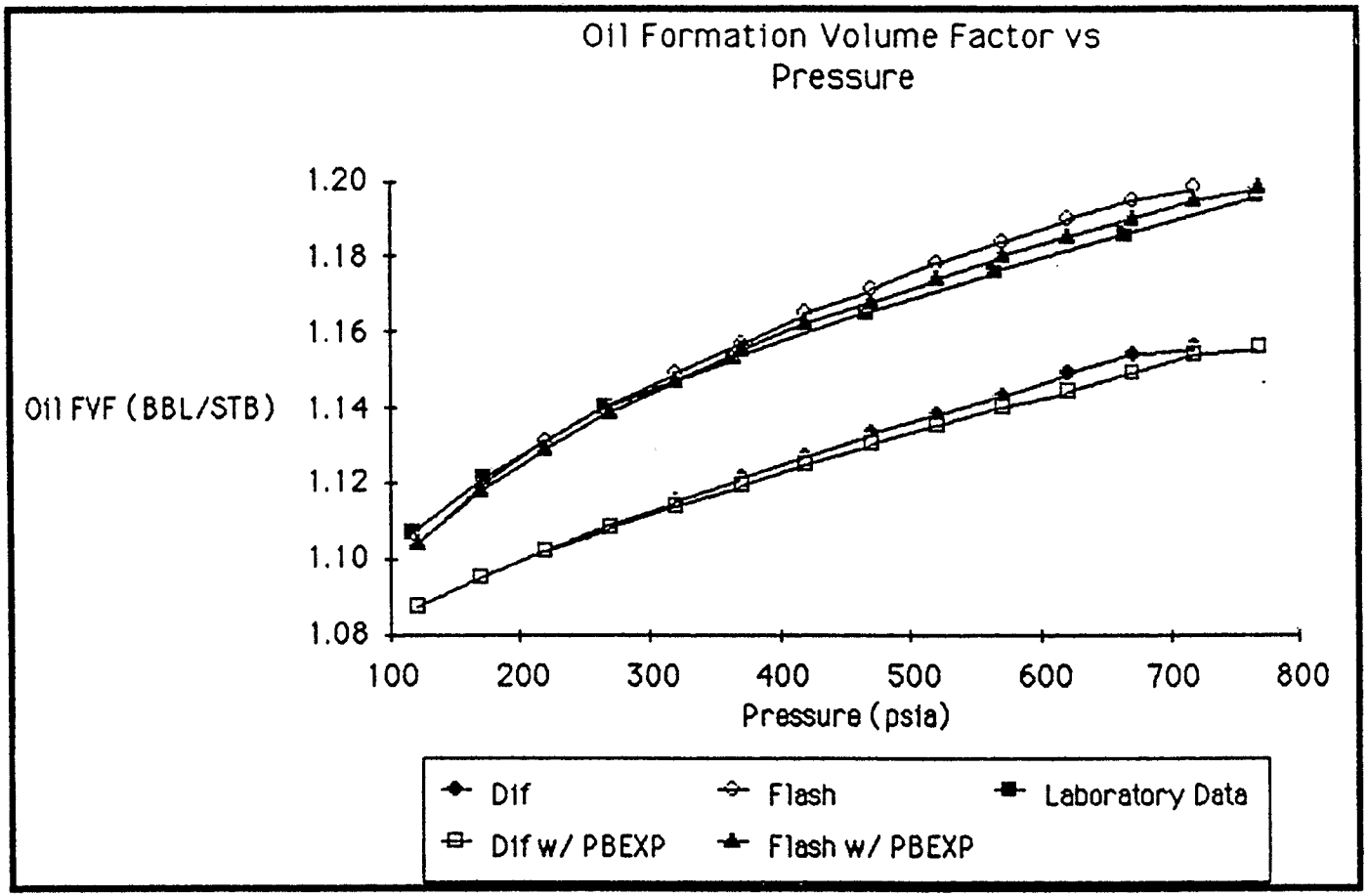


Figure 4.2 Black Oil Sample 1, Oil Formation Volume Factor

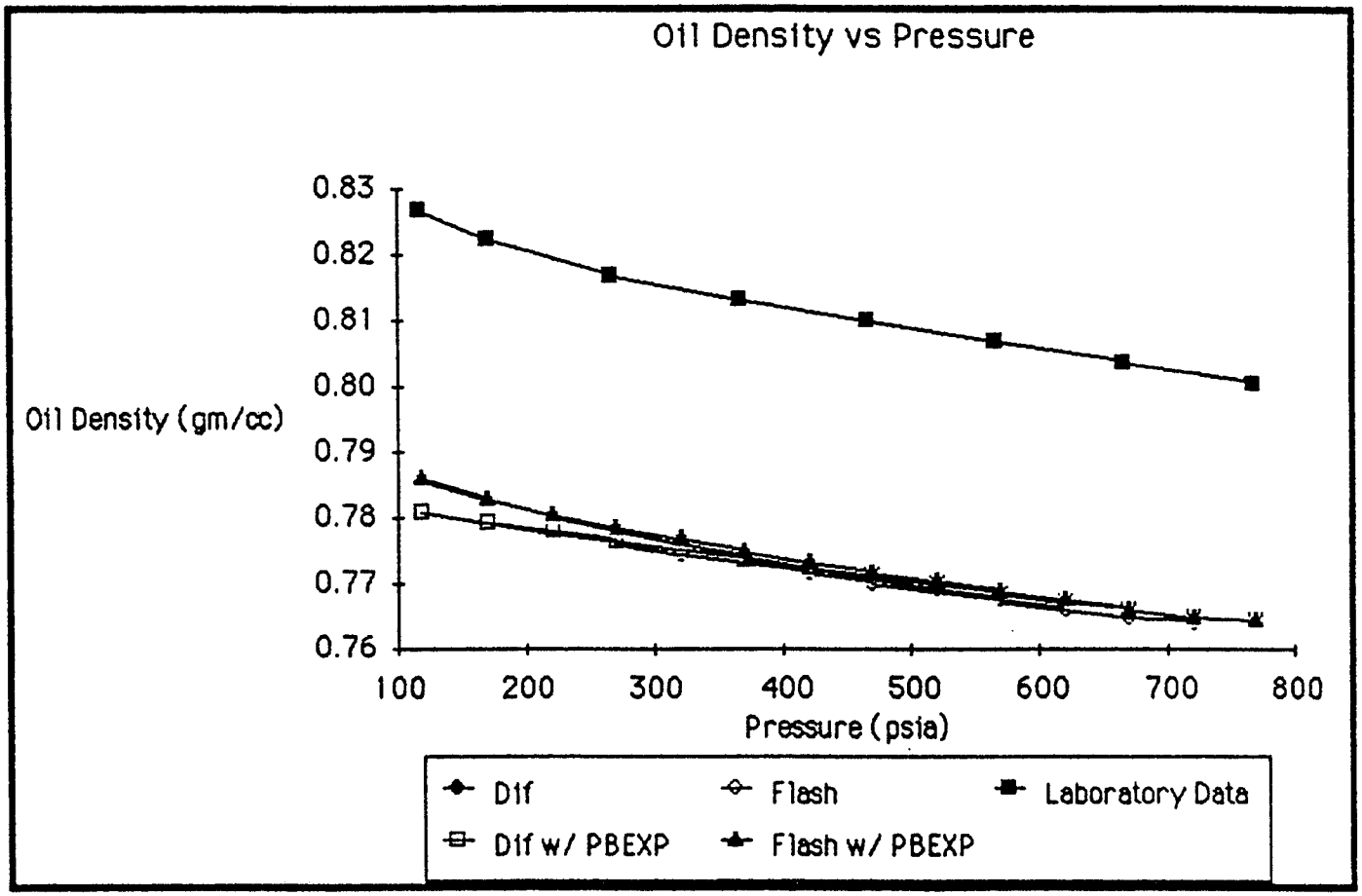


Figure 4.3 Black Oil Sample 1, Oil Density

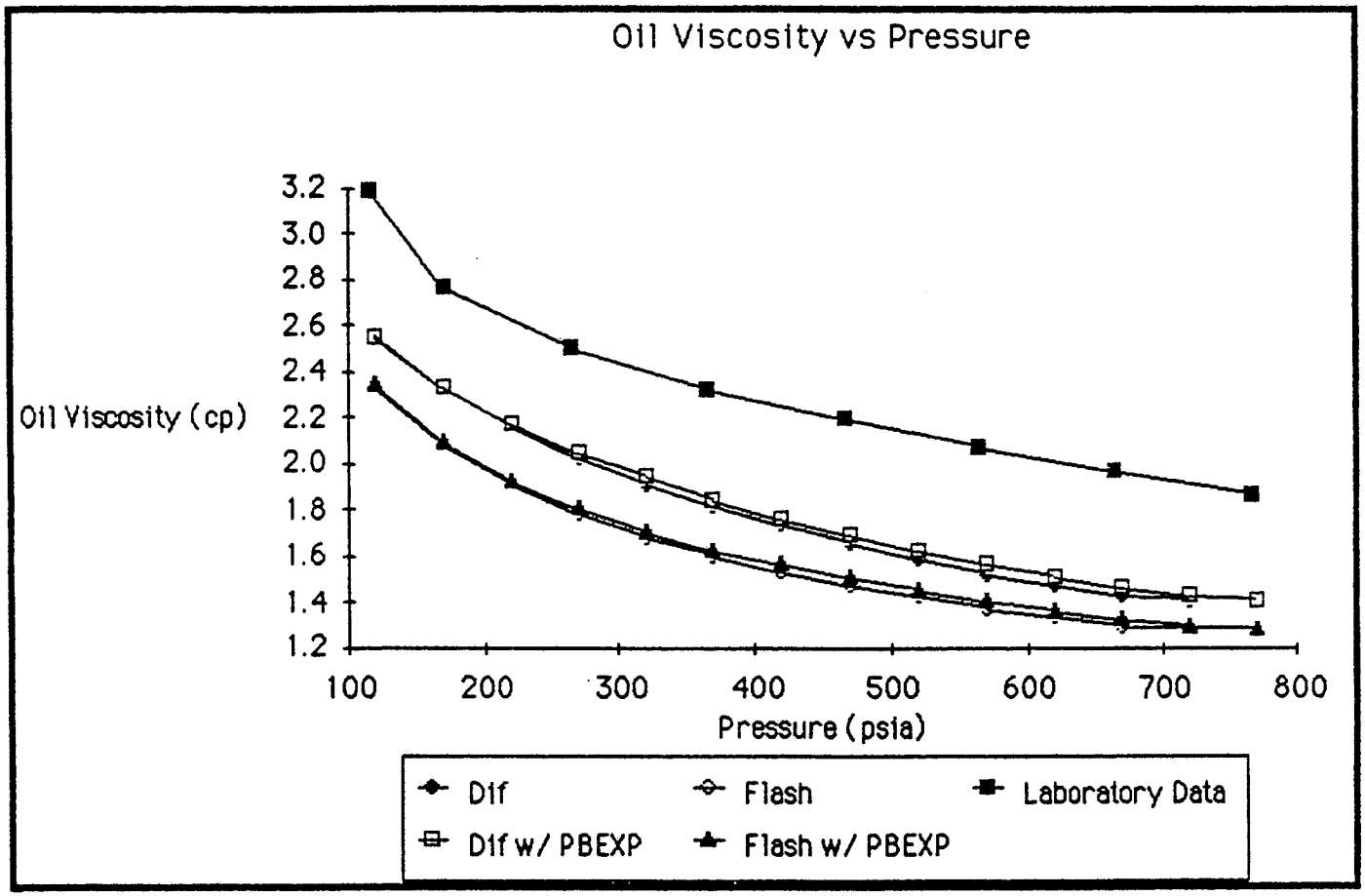


Figure 4.4 Black Oil Sample 1, Oil Viscosity

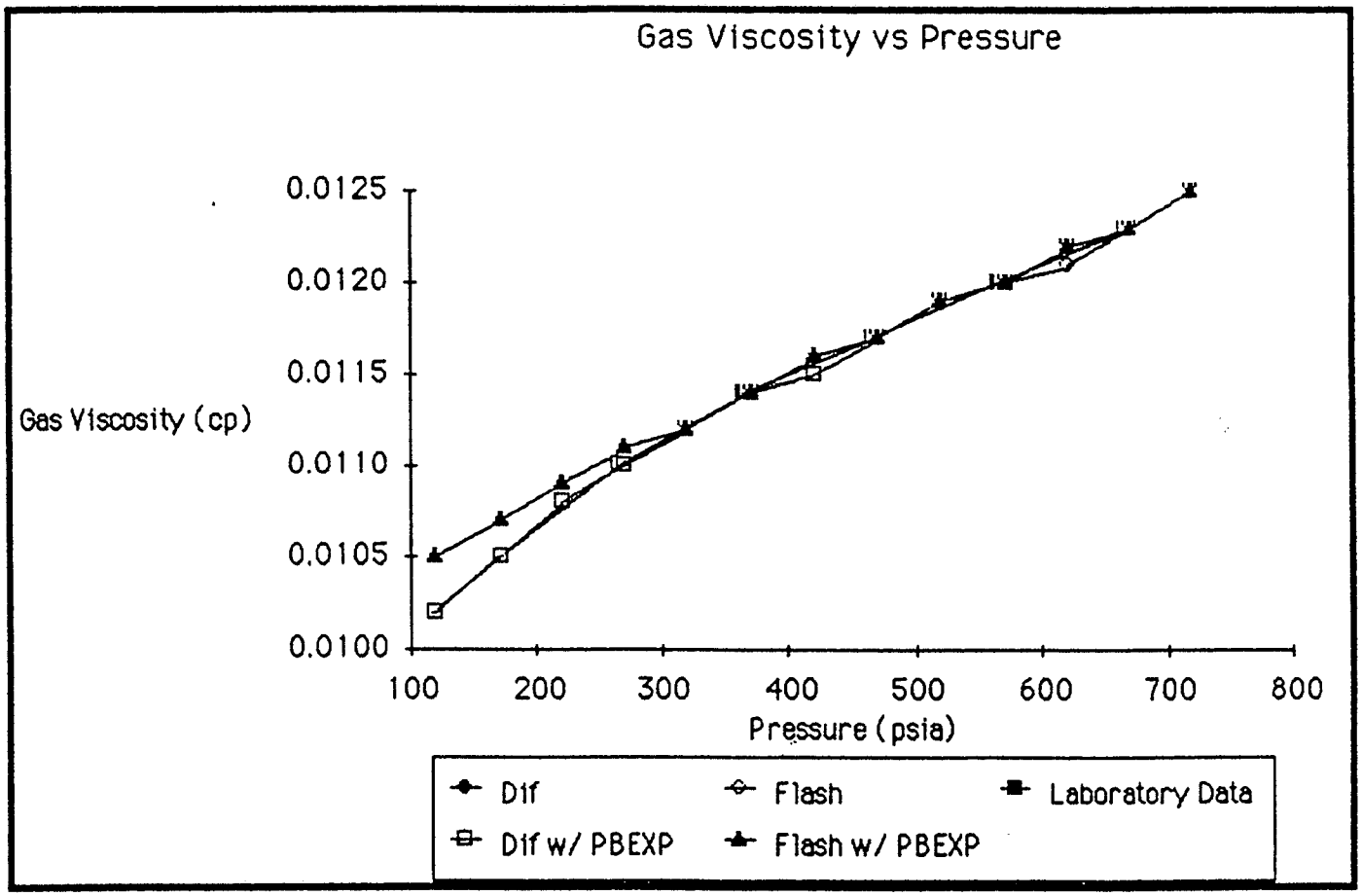


Figure 4.5 Black Oil Sample 1, Gas Viscosity

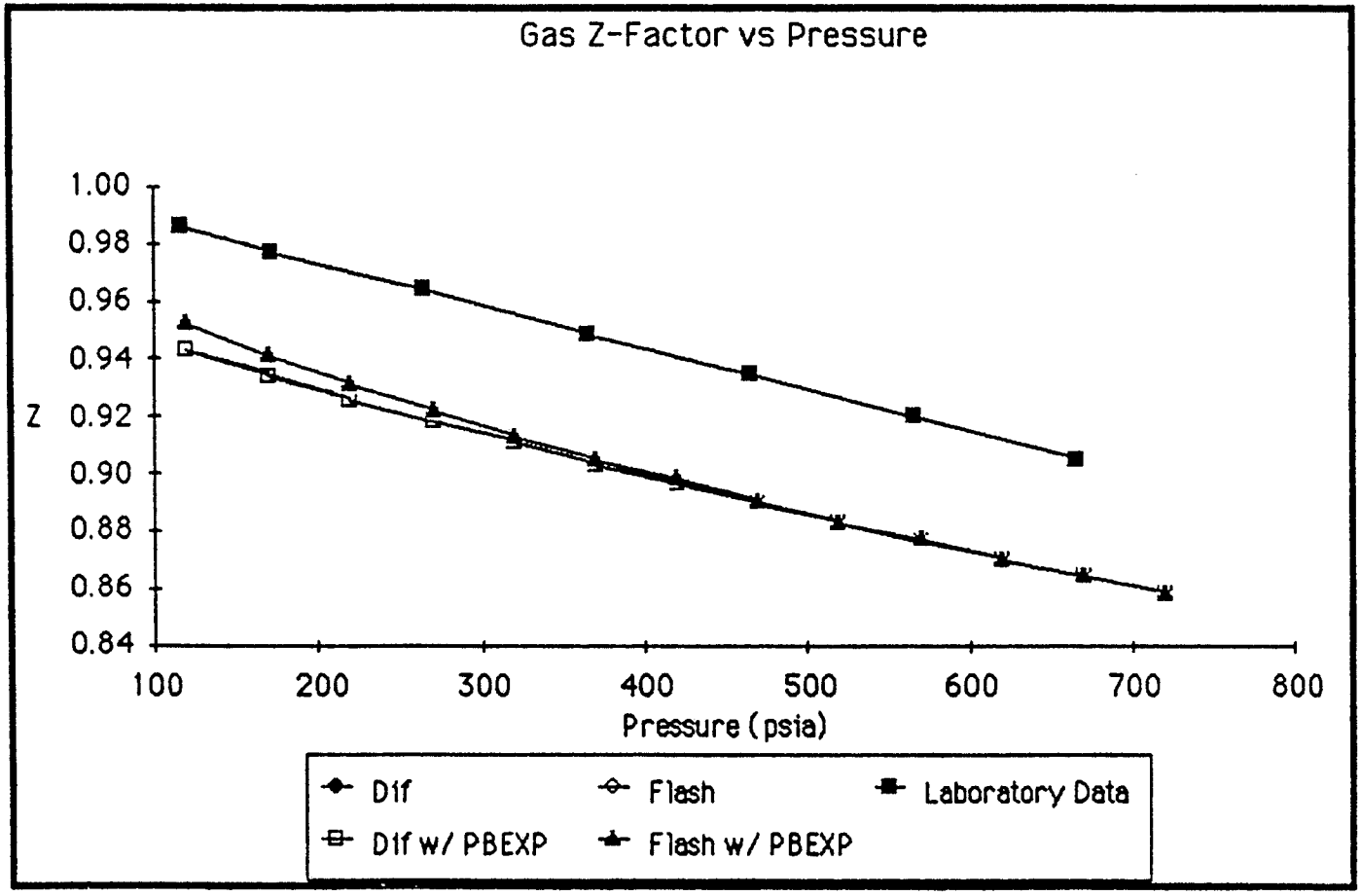


Figure 4.6 Black Oil Sample 1, Gas Z-Factor

Table 4.3 Summary of Results for Black Oil Sample 1

	Differential Vaporization		Flash Vaporization	
PVT Property	AMPE (%)	AAPE (%)	AMPE (%)	AAPE (%)
Gas-Oil Ratio	48.8	41.3	9.8	5.1
with PBEXP	56.8	48.77	11.7	8.48
Oil FVF	2.8	2.6	0.7	0.46
with PBEXP	3.14	2.88	0.34	0.26
Oil Density	5.3	4.73	5.2	4.9
with PBEXP	5.12	4.76	4.63	4.55
Oil Viscosity	26.47	21.67	33.33	30.16
with PBEXP	25	20.6	32.35	29.54
Gas Viscosity	0.86	0.29	1.4	0.56
with PBEXP	0.85	0.28	1.44	0.55
Gas Z-Factor	4.8	4.6	4.8	4.43
with PBEXP	4.62	4.55	4.56	4.31
Average Error		12.53		7.60
with PBEXP		13.64		7.95

Table 4.4 Black Oil Sample 2 Output

```
                ##########################
                # BLACK OIL PVT ANALYSIS #
                ##########################

ESTIMATED PROPERTIES OF HEAVY-PLUS ARE :

      NORMAL BOILING POINT TEMP. =  814.60  DEG.F
      CRITICAL TEMPERATURE =   1109.11  DEG.F
      CRITICAL PRESSURE    =    167.57  PSIA
      ACENTRIC FACTOR      =   1.0232

METHOD/CORRELATION USED          PURPOSE
----------------------           -------
GRABOWSKI-DAUBERT                N2-H/C,CO2-H/C AND H2S-H/C BINARY
                                 INTERACTION PARAMETERS ESTIMATION
ACCD. SUCCESSIVE SUBSTITUTION    ITERATIVE ESTIMATION OF K-VALUES

INITIAL RESERVOIR CONDITIONS AND COMPOSITION (GIVEN)
----------------------------------------------------
RESERVOIR TEMPERATURE = 202.0   DEG.F
RESERVOIR PRESSURE    = 1922.70  PSIA
BUBBLE POINT PRESSURE (EXPT.) = NOT GIVEN


COMPONENT                MOLE FRACTION
---------                -------------
N2                          .00200
CO2                         .00330
METHANE                     .29140
ETHANE                      .07850
PROPANE                     .07310
I-BUTANE                    .01210
N-BUTANE                    .03810
I-PENTANE                   .01310
N-PENTANE                   .01620
HEXANES                     .03680
HEPTANES                    .03450
OCTANES                     .03780
NONANES                     .03590
DECANES                     .03170
HEAVY+                      .29550

HEAVY-PLUS:MOLECULAR WEIGHT = 381.
           SPECIFIC GRAVITY =  .92216


CALC.BUBBLE POINT PRESSURE =    1629.70  PSIA
```

Table 4.4 Continued

DIFFERENTIAL VAPORIZATION

PRES (PSIA)	TEMP (DEG.F)	SOLN GOR (SCF/STB)	OIL FVF (BBL/STB)	TOTAL FVF (BBL/STB)	DEG API	OIL DENSITY (GM/CC)	Z FACTOR	GAS FVF (CU.FT/SCF)	GAS GRAVITY (AIR=1)	OIL VISC (CP)	GAS VISC (CP)	RELATIVE VOLUME
1629.7	202.0	293.0	1.274	1.2738	81.5	.6642	.000	.0000	.000	.40	.0000	1.000
1529.7	202.0	282.6	1.269	1.2885	81.2	.6654	.855	.0104	.728	.40	.0159	1.012
1429.7	202.0	262.0	1.260	1.3217	80.4	.6677	.859	.0112	.729	.41	.0156	1.039
1329.7	202.0	241.8	1.251	1.3612	79.7	.6699	.864	.0121	.730	.43	.0154	1.071
1229.7	202.0	221.9	1.241	1.4084	79.0	.6722	.869	.0132	.732	.44	.0151	1.109
1129.7	202.0	202.4	1.233	1.4655	78.3	.6745	.874	.0144	.735	.45	.0149	1.156
1029.7	202.0	183.2	1.224	1.5354	77.6	.6768	.880	.0159	.740	.46	.0146	1.212
929.7	202.0	164.4	1.215	1.6224	76.9	.6791	.886	.0178	.745	.48	.0144	1.283
829.7	202.0	145.9	1.206	1.7323	76.2	.6814	.892	.0201	.753	.49	.0142	1.372
729.7	202.0	127.5	1.198	1.8756	75.5	.6837	.899	.0230	.762	.51	.0140	1.489
629.7	202.0	109.4	1.189	2.0676	74.8	.6860	.907	.0269	.776	.53	.0137	1.644
529.7	202.0	91.5	1.180	2.3344	74.1	.6883	.914	.0322	.794	.55	.0135	1.862
429.7	202.0	73.8	1.171	2.7357	73.4	.6906	.922	.0401	.821	.58	.0132	2.184
329.7	202.0	56.0	1.162	3.3859	72.7	.6929	.931	.0527	.860	.60	.0129	2.707
229.7	202.0	38.1	1.153	4.6179	72.0	.6952	.939	.0763	.926	.64	.0125	3.693
129.7	202.0	19.2	1.142	7.7947	71.3	.6976	.948	.1365	1.052	.68	.0119	6.219
14.7	60.0	.0	1.000	52.3394	48.0	.7881	.986	.9839	1.319	.74	.0083	41.331

FLASH VAPORIZATION

PRES (PSIA)	TEMP (DEG.F)	SOLN GOR (SCF/STB)	OIL FVF (BBL/STB)	TOTAL FVF (BBL/STB)	DEG API	OIL DENSITY (GM/CC)	Z FACTOR	GAS FVF (CU.FT/SCF)	GAS GRAVITY (AIR=1)	OIL VISC (CP)	GAS VISC (CP)	RELATIVE VOLUME
1629.7	202.0	377.4	1.315	1.3154	81.5	.6642	.000	.0000	.000	.40	.0000	1.000
1529.7	202.0	344.5	1.311	1.3308	81.2	.6654	.855	.0104	.728	.40	.0159	1.011
1429.7	202.0	344.5	1.301	1.3663	80.4	.6678	.859	.0112	.730	.41	.0156	1.037
1329.7	202.0	322.7	1.291	1.4068	79.6	.6702	.863	.0121	.732	.42	.0154	1.068
1229.7	202.0	301.1	1.281	1.4599	78.9	.6727	.868	.0132	.734	.43	.0151	1.105
1129.7	202.0	279.7	1.271	1.5221	78.1	.6751	.873	.0144	.738	.44	.0149	1.150
1029.7	202.0	258.4	1.261	1.5989	77.3	.6776	.879	.0159	.742	.45	.0146	1.204
929.7	202.0	237.1	1.251	1.6954	76.5	.6802	.886	.0178	.747	.47	.0144	1.273
829.7	202.0	215.7	1.241	1.8191	75.7	.6828	.892	.0201	.754	.48	.0142	1.359
729.7	202.0	194.1	1.230	1.9819	74.9	.6854	.900	.0230	.763	.50	.0140	1.472
629.7	202.0	172.1	1.219	2.2036	74.1	.6882	.908	.0269	.774	.52	.0137	1.622
529.7	202.0	149.4	1.208	2.5195	73.3	.6910	.916	.0323	.788	.54	.0135	1.832
429.7	202.0	125.6	1.195	2.9991	72.4	.6941	.926	.0402	.806	.57	.0133	2.141
329.7	202.0	100.1	1.181	3.7995	71.4	.6973	.936	.0530	.831	.60	.0131	2.632
229.7	202.0	71.4	1.164	5.3695	70.4	.7010	.948	.0770	.866	.64	.0128	3.513
129.7	202.0	37.4	1.142	9.5212	69.1	.7054	.961	.1384	.921	.71	.0124	5.480
14.7	60.0	.0	1.000	67.3893	46.1	.7968	.993	.9907	.933	.83	.0095	51.541

Table 4.5 Black Oil Sample 2 Output with Experimental Bubble Point Given

```
                ****************************
                * BLACK OIL PVT ANALYSIS *
                ****************************

ESTIMATED PROPERTIES OF HEAVY-PLUS ARE :

      NORMAL BOILING POINT TEMP. =  814.60  DEG.F
      CRITICAL TEMPERATURE =   1109.11  DEG.F
      CRITICAL PRESSURE    =    167.57  PSIA
      ACENTRIC FACTOR      =   1.0232

METHOD/CORRELATION USED          PURPOSE
-----------------------          -------
GRABOWSKI-DAUBERT                N2-H/C,CO2-H/C AND H2S-H/C BINARY
                                 INTERACTION PARAMETERS ESTIMATION
ACCD. SUCCESSIVE SUBSTITUTION    ITERATIVE ESTIMATION OF K-VALUES

INITIAL RESERVOIR CONDITIONS AND COMPOSITION (GIVEN)
----------------------------------------------------
RESERVOIR TEMPERATURE = 202.0   DEG.F
RESERVOIR PRESSURE    = 1922.70  PSIA
BUBBLE POINT PRESSURE (EXPT.) =   1922.70  PSIA


COMPONENT                MOLE FRACTION
---------                -------------
N2                          .00200
CO2                         .00330
METHANE                     .29140
ETHANE                      .07850
PROPANE                     .07310
I-BUTANE                    .01210
N-BUTANE                    .03810
I-PENTANE                   .01310
N-PENTANE                   .01620
HEXANES                     .03680
HEPTANES                    .03450
OCTANES                     .03780
NONANES                     .03590
DECANES                     .03170
HEAVY+                      .29550

HEAVY-PLUS:MOLECULAR WEIGHT = 381.
           SPECIFIC GRAVITY =  .92216


CALC.BUBBLE POINT PRESSURE =    1927.70  PSIA
```

Table 4.5 Continued

DIFFERENTIAL VAPORIZATION

PRES (PSIA)	TEMP (DEG.F)	SOLN GOR (SCF/STB)	OIL FVF (BBL/STB)	TOTAL FVF (BBL/STB)	DEG API	OIL DENSITY (GM/CC)	Z FACTOR	GAS FVF (CU.FT/SCF)	GAS GRAVITY (AIR=1)	OIL VISC (CP)	GAS VISC (CP)	RELATIVE VOLUME
1927.7	202.0	302.3	1.277	1.2766	81.1	.6656	.000	.0000	.000	.40	.0000	1.000
1827.7	202.0	293.6	1.273	1.2861	80.8	.6665	.842	.0086	.742	.40	.0169	1.008
1727.7	202.0	276.5	1.265	1.3073	80.3	.6682	.845	.0091	.742	.41	.0165	1.025
1627.7	202.0	259.5	1.258	1.3319	79.7	.6700	.848	.0097	.742	.42	.0162	1.045
1527.7	202.0	242.8	1.250	1.3607	79.1	.6718	.852	.0104	.742	.43	.0159	1.068
1427.7	202.0	226.2	1.243	1.3947	78.6	.6736	.856	.0112	.743	.44	.0156	1.096
1327.7	202.0	209.9	1.234	1.4349	78.0	.6754	.861	.0121	.745	.45	.0154	1.128
1227.7	202.0	193.7	1.228	1.4831	77.5	.6772	.866	.0132	.747	.46	.0151	1.167
1127.7	202.0	177.7	1.221	1.5413	76.9	.6790	.871	.0144	.751	.47	.0149	1.215
1027.7	202.0	162.0	1.214	1.6122	76.3	.6808	.877	.0159	.756	.48	.0146	1.272
927.7	202.0	146.2	1.207	1.7009	75.8	.6827	.883	.0178	.762	.50	.0144	1.344
827.7	202.0	130.6	1.199	1.8133	75.2	.6846	.890	.0201	.770	.51	.0141	1.435
727.7	202.0	115.0	1.192	1.9594	74.6	.6864	.897	.0230	.781	.53	.0139	1.554
627.7	202.0	99.6	1.185	2.1554	74.1	.6883	.904	.0269	.796	.55	.0137	1.712
527.7	202.0	84.2	1.177	2.4301	73.5	.6903	.911	.0322	.817	.57	.0134	1.934
427.7	202.0	68.8	1.170	2.8389	72.9	.6922	.919	.0401	.846	.59	.0132	2.263
327.7	202.0	53.2	1.162	3.5064	72.3	.6942	.927	.0528	.891	.62	.0128	2.799
227.7	202.0	37.1	1.153	4.7771	71.7	.6962	.936	.0767	.963	.65	.0124	3.813
127.7	202.0	19.8	1.143	8.0909	71.1	.6983	.945	.1381	1.103	.69	.0118	6.441
14.7	60.0	.0	1.000	53.9395	47.8	.7891	.986	.9832	1.365	.75	.0082	42.495

FLASH VAPORIZATION

PRES (PSIA)	TEMP (DEG.F)	SOLN GOR (SCF/STB)	OIL FVF (BBL/STB)	TOTAL FVF (BBL/STB)	DEG API	OIL DENSITY (GM/CC)	Z FACTOR	GAS FVF (CU.FT/SCF)	GAS GRAVITY (AIR=1)	OIL VISC (CP)	GAS VISC (CP)	RELATIVE VOLUME
1927.7	202.0	384.8	1.318	1.3182	81.1	.6656	.000	.0000	.000	.40	.0000	1.000
1827.7	202.0	375.6	1.314	1.3282	80.8	.6665	.842	.0086	.742	.40	.0169	1.007
1727.7	202.0	357.4	1.306	1.3506	80.2	.6683	.845	.0091	.742	.41	.0165	1.024
1627.7	202.0	339.4	1.298	1.3768	79.6	.6702	.848	.0097	.743	.41	.0162	1.043
1527.7	202.0	321.5	1.290	1.4076	79.1	.6720	.851	.0104	.743	.42	.0159	1.065
1427.7	202.0	303.6	1.282	1.4440	78.5	.6739	.856	.0112	.745	.43	.0156	1.092
1327.7	202.0	285.8	1.274	1.4875	77.9	.6759	.860	.0121	.746	.44	.0154	1.123
1227.7	202.0	268.0	1.266	1.5398	77.3	.6778	.865	.0132	.749	.45	.0151	1.161
1127.7	202.0	250.2	1.258	1.6035	76.6	.6798	.871	.0144	.752	.46	.0149	1.206
1027.7	202.0	232.3	1.250	1.6823	76.0	.6819	.877	.0159	.757	.47	.0146	1.262
927.7	202.0	214.3	1.241	1.7810	75.4	.6840	.883	.0178	.762	.49	.0144	1.331
827.7	202.0	195.9	1.233	1.9079	74.7	.6861	.890	.0201	.769	.50	.0141	1.420
727.7	202.0	177.2	1.223	2.0752	74.0	.6884	.898	.0230	.778	.52	.0139	1.535
627.7	202.0	157.8	1.214	2.3031	73.3	.6908	.906	.0270	.789	.53	.0137	1.689
527.7	202.0	137.6	1.203	2.6282	72.6	.6933	.915	.0324	.804	.56	.0135	1.903
427.7	202.0	116.2	1.192	3.1227	71.8	.6959	.925	.0404	.822	.58	.0132	2.220
327.7	202.0	92.8	1.178	3.9495	71.0	.6989	.936	.0533	.847	.61	.0130	2.724
227.7	202.0	66.3	1.162	5.5679	70.0	.7022	.947	.0777	.883	.66	.0127	3.631
127.7	202.0	34.0	1.140	9.9192	68.8	.7063	.961	.1405	.940	.73	.0124	5.666
14.7	60.0	.0	1.000	68.8794	45.9	.7976	.993	.9906	.951	.84	.0094	52.414

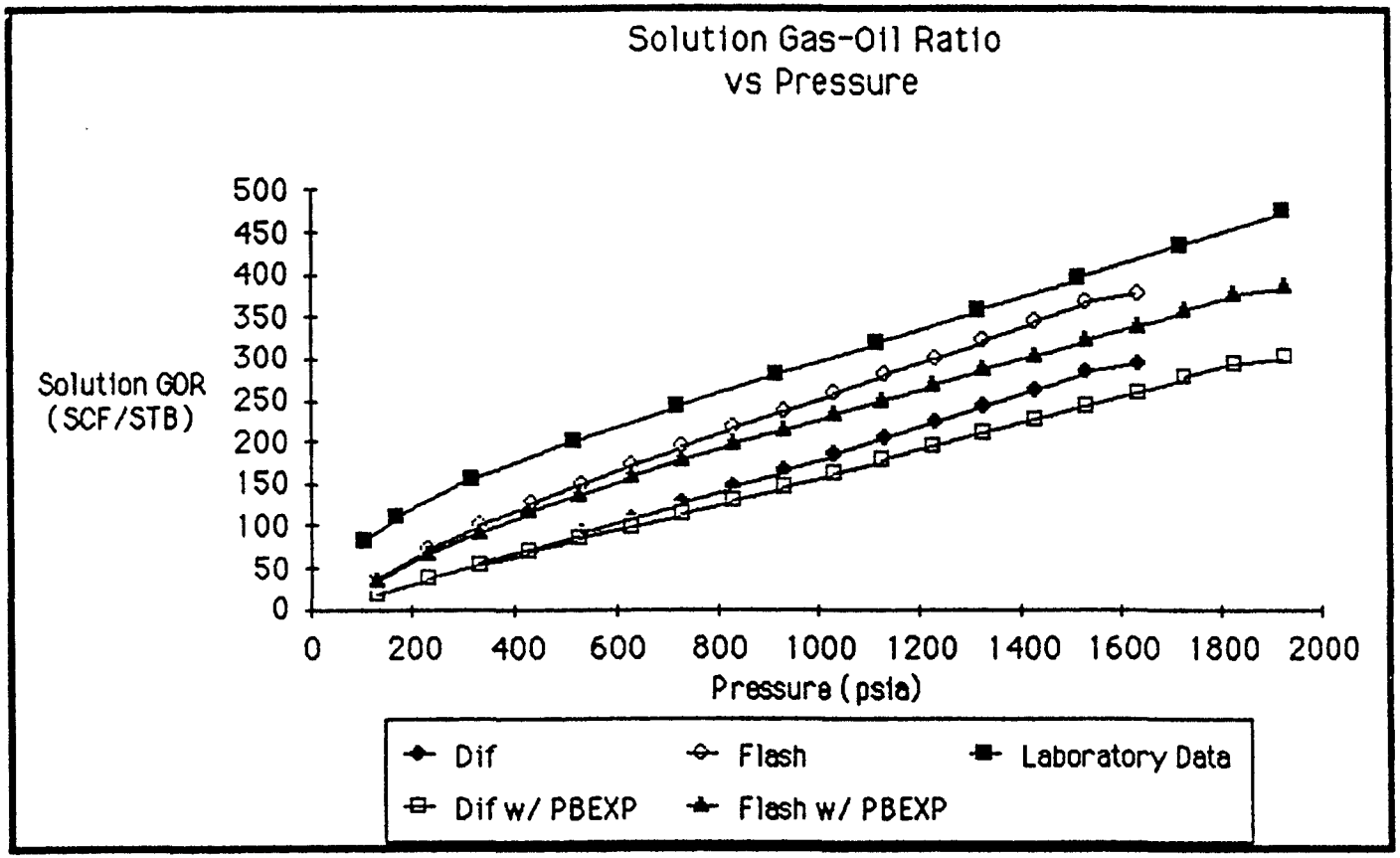


Figure 4.7 Black Oil Sample 2, Gas-Oil Ratio

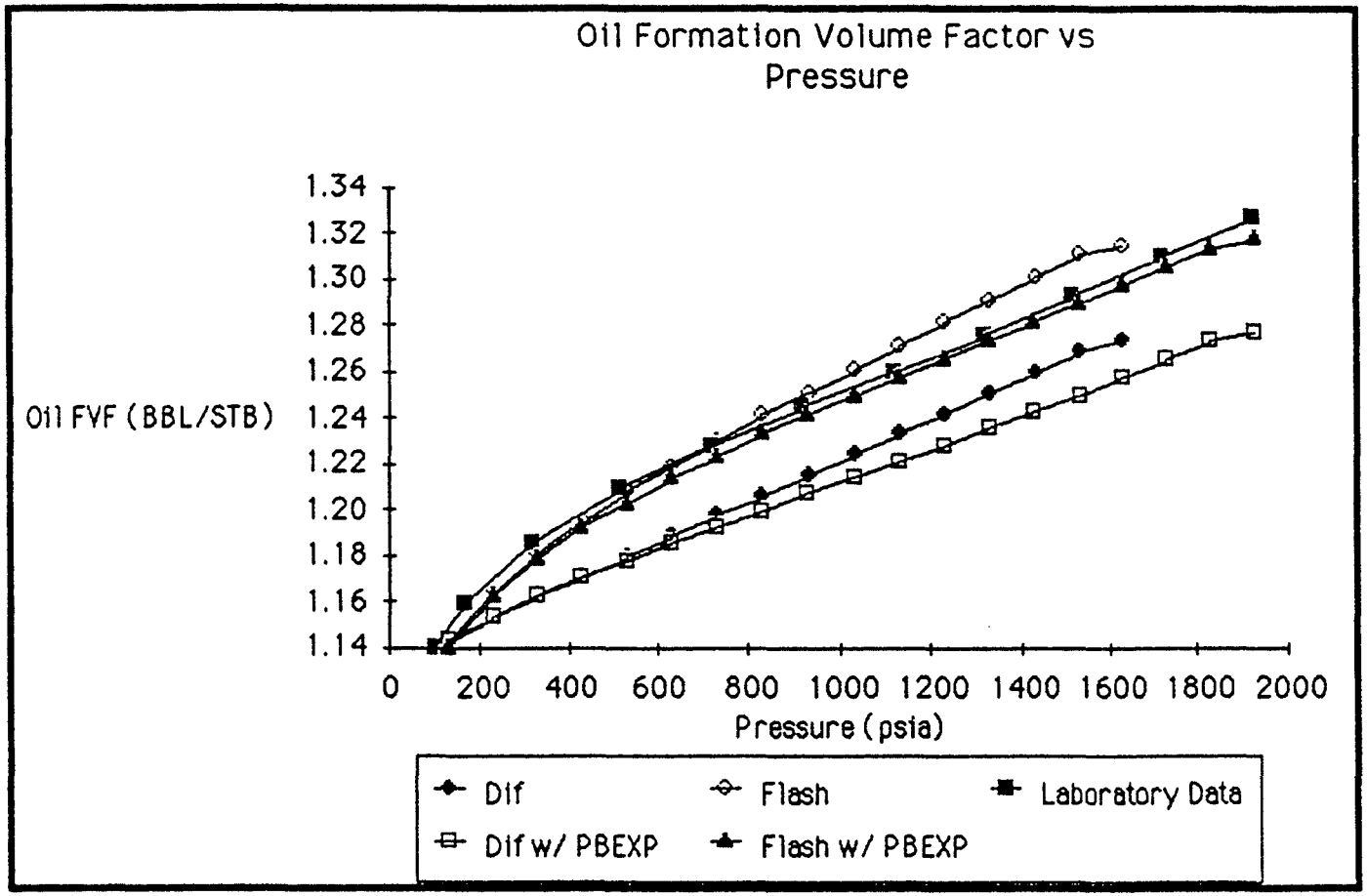


Figure 4.8 Black Oil Sample 2, Oil Formation Volume Factor

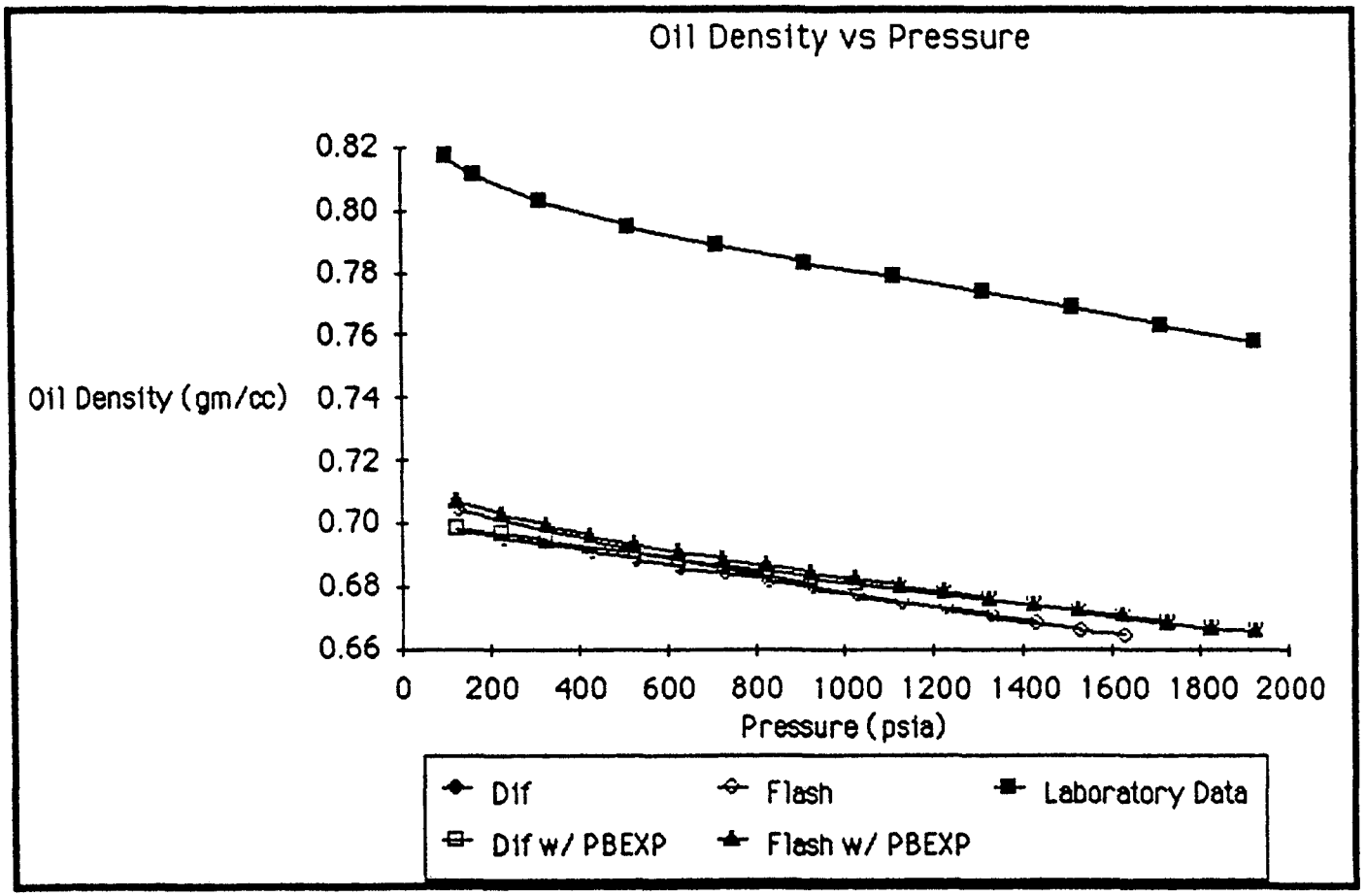


Figure 4.9 Black Oil Sample 2, Oil Density

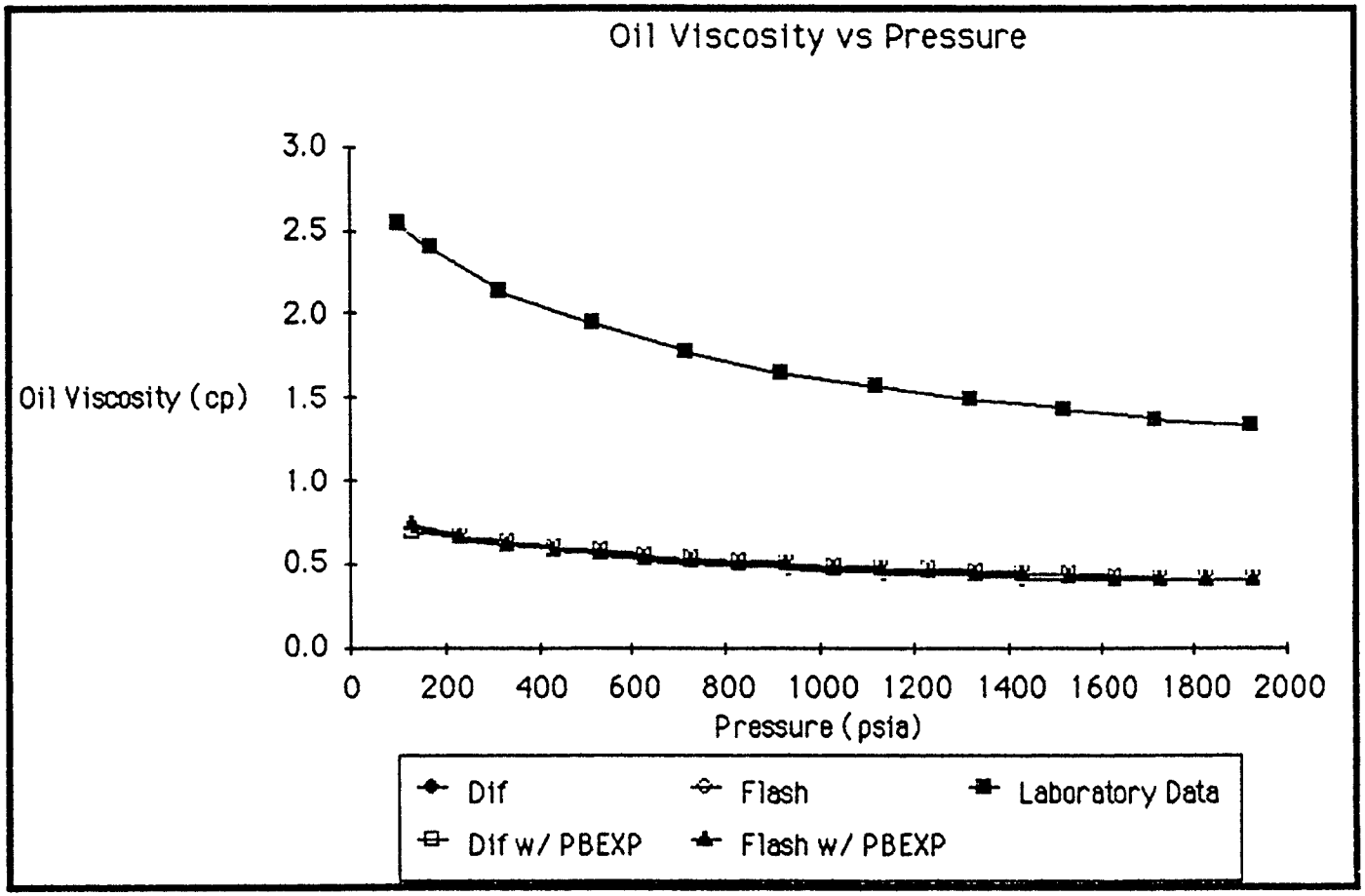


Figure 4.10 Black Oil Sample 2, Oil Viscosity

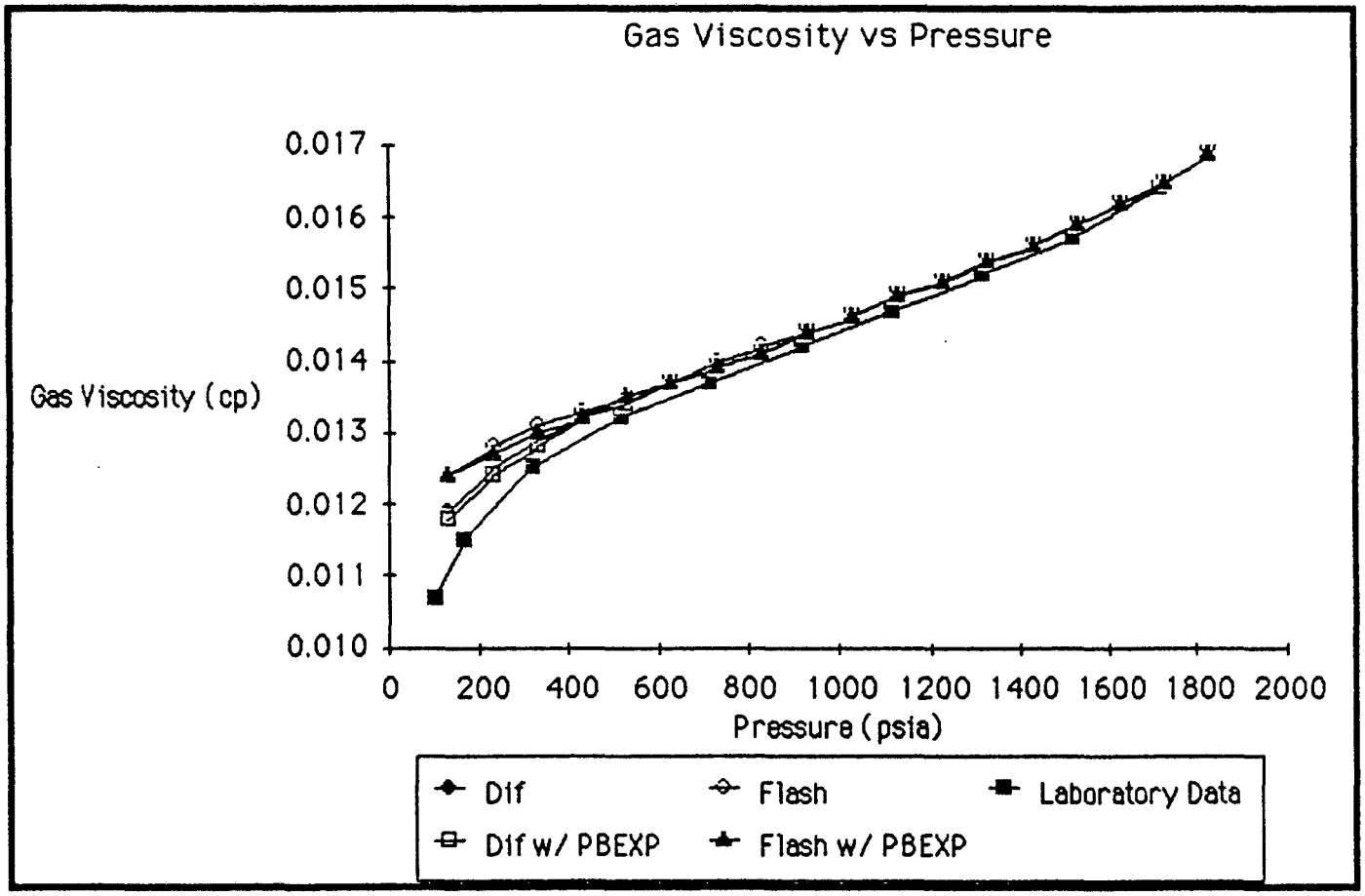


Figure 4.11 Black Oil Sample 2, Gas Viscosity

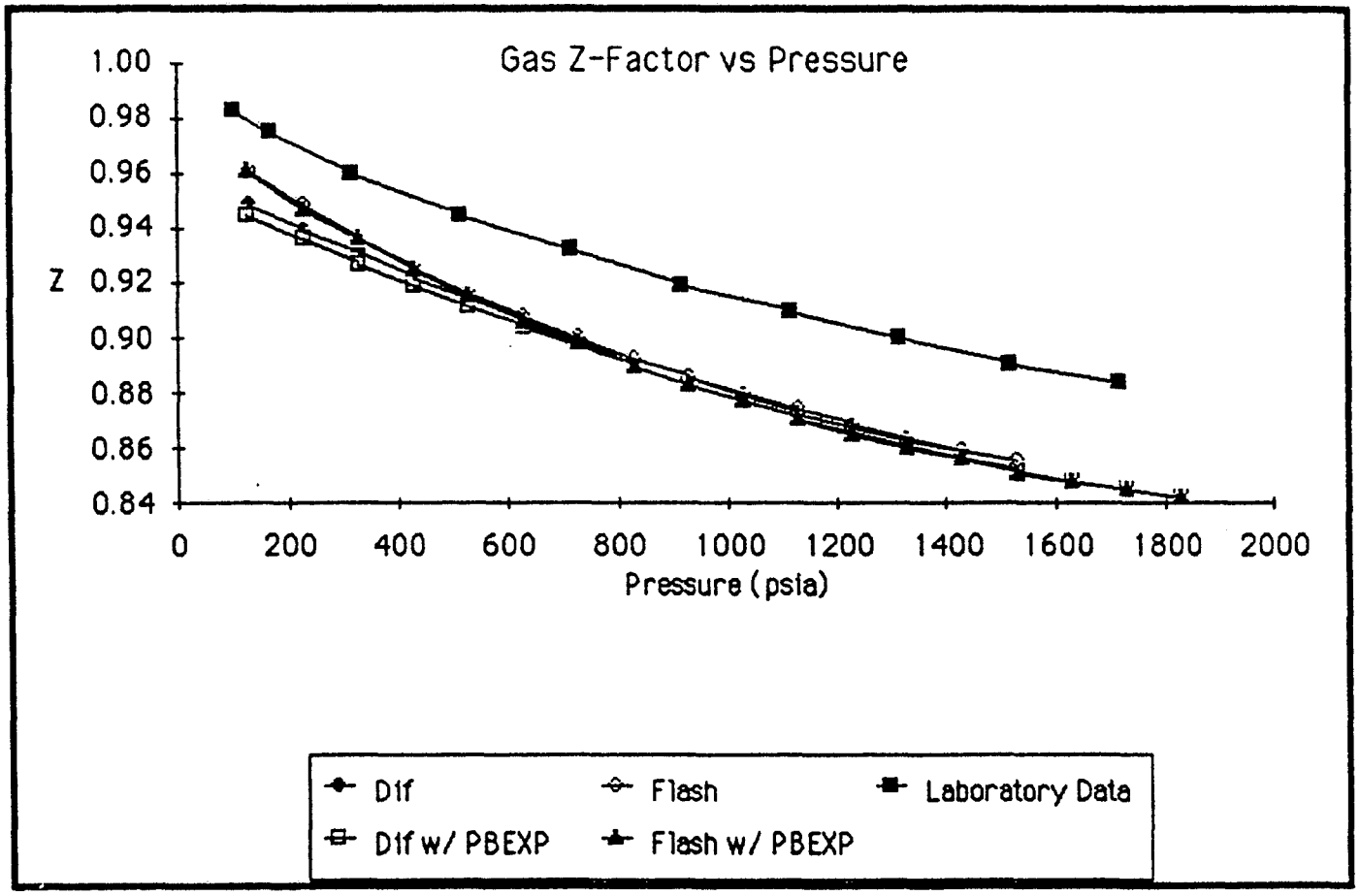


Figure 4.12 Black Oil Sample 2, Gas Z-Factor

Table 4.6 Summary of Results for Black Oil Sample 2

	Differential Vaporization		Flash Vaporization	
PVT Property	AMPE (%)	AAPE (%)	AMPE (%)	AAPE (%)
Gas-Oil Ratio	75	47.75	50	30.25
with PBEXP	65	49.25	37	25.75
Oil FVF	2.4	1.98	0.69	0.36
with PBEXP	3.4	2.77	0.58	0.42
Oil Density	14.2	13.17	13.6	13
with PBEXP	13.5	12.9	13.2	12.75
Oil Viscosity	70.5	69	70.7	69.6
with PBEXP	70	69	70.6	69.7
Gas Viscosity	2.34	1.24	3.12	1.5
with PBEXP	2.4	1.2	3.1	1.45
Gas Z-Factor	2.4	1.98	0.69	0.36
with PBEXP	4.41	3.92	4.41	3.74
Average Error		22.52		19.18
with PBEXP		23.17		18.97

4.3 Volatile oil Samples

Volatile oil sample 1 had a laboratory measured bubble point pressure of 3416.7 psia. The program calculated the bubble point pressure to be 3156.7 psia, an error of 7.61%. Volatile oil sample 2 had a laboratory measured bubble point pressure of 5092.7 psia. The program calculated the bubble point pressure to be 4743.7 psia, an error of 6.85%.

In both samples the calculated PVT properties for flash vaporization gave smaller errors than those for differential vaporization, eventhough the experimental values were based on differential vaporization. Also, it should be noted that supplying the experimental bubble point pressure for matching, generally gave larger errors for most properties.

The output the volatile oil samples are given in Tables 4.7, 4.8, 4.10, and 4.11. The results are presented graphically in Figures 4.13 through 4.24 and compared numerically in Tables 4.9 and 4.12.

Table 4.7 Volatile Oil Sample 1 Output

```
                    ********************************
                    * VOLATILE OIL PVT ANALYSIS *
                    ********************************

ESTIMATED PROPERTIES OF HEAVY-PLUS ARE :

      NORMAL BOILING POINT TEMP. =  413.04  DEG.F
      CRITICAL TEMPERATURE =    744.09  DEG.F
      CRITICAL PRESSURE    =    321.53  PSIA
      ACENTRIC FACTOR      =    .5242

METHOD/CORRELATION USED          PURPOSE
-----------------------          -------
ACCD. SUCCESSIVE SUBSTITUTION    ITERATIVE ESTIMATIO N OF K-VALUES
GRABOWSKI-DAUBERT                N2-H/C,CO2-H/C AND H2S-H/C BINARY
                                 INTERACTION PARAMETERS ESTIMATION

INITIAL RESERVOIR CONDITIONS AND COMPOSITION (GIVEN)
----------------------------------------------------
RESERVOIR TEMPERATURE =    306.0   DEG.F
RESERVOIR PRESSURE    =    3416.70  PSIA
BUBBLE POINT PRESSURE (EXPT.) = NOT GIVEN


COMPONENT                MOLE FRACTION
---------                -------------
N2                          .00250
H2S                         .27830
CO2                         .03730
METHANE                     .36750
ETHANE                      .07280
PROPANE                     .04210
I-BUTANE                    .00970
N-BUTANE                    .02240
I-PENTANE                   .01030
N-PENTANE                   .01210
HEXANES                     .01890
HEAVY+                      .12610

HEAVY-PLUS:MOLECULAR WEIGHT =    172.
           SPECIFIC GRAVITY =     .81210


CALCULATED BUBBLE POINT PRESSURE =    3156.70  PSIA
```

Table 4.7 Continued

FLASH VAPORIZATION

PRES (PSIA)	TEMP (DEG.F)	SOLN GOR (SCF/STB)	OIL FVF (BBL/STB)	TOTAL FVF (BBL/STB)	DEG API	OIL DENSITY (GM/CC)	Z FACTOR	GAS FVF (CU.FT/SCF)	GAS GRAVITY (AIR=1)	OIL VISC (CP)	GAS VISC (CP)	RELATIVE VOLUME
3156.7	306.0	4344.9	4.303	4.303	202.0	.4243	.900	.0000	.000	.108	.0000	1.000
2956.7	306.0	3292.3	3.418	4.465	183.3	.4494	.749	.0055	1.236	.122	.0325	1.031
2756.7	306.0	2467.1	2.776	4.791	161.6	.4827	.760	.0060	1.168	.137	.0280	1.102
2556.7	306.0	2014.7	2.445	5.170	146.8	.5085	.770	.0065	1.124	.148	.0251	1.187
2356.7	306.0	1696.5	2.222	5.623	135.4	.5302	.780	.0072	1.093	.158	.0230	1.289
2156.7	306.0	1450.2	2.056	6.170	126.1	.5492	.791	.0079	1.070	.167	.0213	1.413
1956.7	306.0	1244.2	1.921	6.845	118.2	.5666	.802	.0089	1.053	.177	.0199	1.566
1756.7	306.0	1069.4	1.808	7.689	111.5	.5824	.814	.0100	1.040	.186	.0188	1.758
1556.7	306.0	914.9	1.709	8.772	105.4	.5973	.828	.0115	1.031	.197	.0178	2.005
1356.7	306.0	775.7	1.621	10.201	99.9	.6114	.843	.0134	1.026	.208	.0170	2.331
1156.7	306.0	648.4	1.540	12.157	94.9	.6250	.858	.0160	1.024	.220	.0163	2.777
956.7	306.0	529.5	1.465	14.977	90.2	.6383	.876	.0198	1.027	.234	.0156	3.421
756.7	306.0	417.1	1.394	19.351	85.8	.6513	.894	.0255	1.034	.251	.0151	4.421
556.7	306.0	307.6	1.323	26.973	81.4	.6645	.914	.0355	1.048	.272	.0146	6.163
356.7	306.0	197.7	1.252	43.378	77.1	.6783	.937	.0567	1.069	.303	.0141	9.912
156.7	306.0	80.8	1.172	102.394	72.4	.6938	.962	.1326	1.107	.356	.0137	23.405
14.7	60.0	.0	1.006	771.285	44.9	.7931	.993	.9964	1.078	.431	.0090	179.799

CUMULATIVE RECOVERY DURING DEPLETION (PER MMSCF OF ORIGINAL FLUID)

RESERVOIR PRESSURE (PSIA)	LIQUID VOLUME (%)	GAS PHASE (MSCF)	PLANT PRODUCTS IN GAS PHASE, GALLONS ETHANE	PROPANE	BUTANES	PENTANES+	GPM ETHANE+	PROPANE+	BUTANE+	PENTANE+
3156.7	100.0	.00	0.	0.	0.	0.	.00	.00	.00	.00
2956.7	79.4	27.27	56.	30.	24.	129.	8.78	6.73	5.62	4.72
2756.7	64.5	81.42	169.	90.	71.	313.	7.91	5.83	4.73	3.85
2556.7	56.8	136.50	286.	150.	118.	448.	7.34	5.25	4.15	3.28
2356.7	51.6	192.13	405.	212.	165.	552.	6.94	4.84	3.73	2.87
2156.7	47.8	247.96	526.	274.	212.	635.	6.65	4.52	3.42	2.56
1956.7	44.6	304.17	650.	338.	260.	705.	6.42	4.28	3.17	2.32
1756.7	42.0	360.22	775.	403.	309.	764.	6.25	4.10	2.98	2.13
1556.7	39.7	416.23	903.	470.	359.	822.	6.14	3.97	2.84	1.98
1356.7	37.7	472.04	1033.	540.	412.	879.	6.07	3.88	2.73	1.86
1156.7	35.8	527.55	1166.	614.	468.	940.	6.04	3.83	2.67	1.78
956.7	34.0	582.76	1303.	693.	529.	1012.	6.07	3.83	2.64	1.74
756.7	32.4	637.60	1446.	781.	598.	1103.	6.16	3.89	2.67	1.73
556.7	30.7	692.36	1596.	883.	682.	1232.	6.34	4.04	2.76	1.78
356.7	29.1	747.49	1754.	1013.	797.	1404.	6.64	4.30	2.94	1.88
156.7	27.2	803.97	1906.	1197.	990.	1713.	7.22	4.85	3.34	2.13
14.7	23.2	859.00	2082.	1430.	1175.	1215.	6.87	4.45	2.78	1.41

DIFFERENTIAL VAPORIZATION

PRES (PSIA)	TEMP (DEG.F)	SOLN GOR (SCF/STB)	OIL FVF (BBL/STB)	TOTAL FVF (BBL/STB)	DEG API	OIL DENSITY (GM/CC)	Z FACTOR	GAS FVF (CU.FT/BCF)	GAS GRAVITY (AIR=1)	OIL VISC (CP)	GAS VISC (CP)	RELATIVE VOLUME
3156.7	306.0	4381.2	4.423	4.423	201.5	.4249	.741	.0051	1.292	.105	.0362	1.000
2956.7	306.0	3599.9	3.794	4.560	189.3	.4411	.753	.0055	1.220	.112	.0318	1.032
2756.7	306.0	2774.7	3.153	4.873	172.2	.4659	.767	.0060	1.144	.123	.0273	1.104
2556.7	306.0	2225.2	2.734	5.257	158.0	.4887	.777	.0066	1.102	.134	.0246	1.191
2356.7	306.0	1829.2	2.443	5.714	146.4	.5091	.785	.0072	1.075	.144	.0227	1.296
2156.7	306.0	1526.4	2.224	6.265	136.7	.5275	.794	.0079	1.057	.153	.0212	1.421
1956.7	306.0	1281.4	2.051	6.938	128.4	.5445	.802	.0089	1.045	.163	.0199	1.574
1756.7	306.0	1077.5	1.909	7.776	121.1	.5603	.811	.0100	1.040	.173	.0188	1.764
1556.7	306.0	903.0	1.799	8.844	114.6	.5750	.821	.0114	1.039	.183	.0179	2.007
1356.7	306.0	750.4	1.688	10.249	108.8	.5889	.832	.0132	1.043	.193	.0171	2.326
1156.7	306.0	614.1	1.597	12.165	103.5	.6021	.844	.0158	1.054	.205	.0163	2.761
956.7	306.0	490.1	1.515	14.923	98.7	.6147	.857	.0193	1.072	.218	.0156	3.387
756.7	306.0	375.2	1.439	19.202	94.2	.6268	.872	.0249	1.100	.234	.0150	4.359
556.7	306.0	266.4	1.367	26.671	90.1	.6385	.890	.0345	1.141	.254	.0144	6.055
356.7	306.0	160.6	1.296	42.793	86.4	.6495	.912	.0552	1.201	.281	.0137	9.716
156.7	306.0	55.9	1.222	101.074	83.2	.6590	.940	.1296	1.294	.327	.0131	22.948
14.7	60.0	.0	1.000	772.588	49.6	.7811	.991	.9889	1.168	.371	.0087	175.411

Table 4.8 Volatile Oil Sample 1 Output with Experimental Bubble Point Given

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*****************************
* VOLATILE OIL PVT ANALYSIS *
*****************************

ESTIMATED PROPERTIES OF HEAVY-PLUS ARE :

      NORMAL BOILING POINT TEMP. =  413.04  DEG.F
      CRITICAL TEMPERATURE =    744.09  DEG.F
      CRITICAL PRESSURE    =    321.53  PSIA
      ACENTRIC FACTOR      =    .5242

METHOD/CORRELATION USED          PURPOSE
-----------------------          -------
ACCD. SUCCESSIVE SUBSTITUTION    ITERATIVE ESTIMATIO N OF K-VALUES
GRABOWSKI-DAUBERT                N2-H/C,CO2-H/C AND H2S-H/C BINARY
                                 INTERACTION PARAMETERS ESTIMATION

INITIAL RESERVOIR CONDITIONS AND COMPOSITION (GIVEN)
----------------------------------------------------
RESERVOIR TEMPERATURE =    306.0   DEG.F
RESERVOIR PRESSURE    =    3416.70  PSIA
BUBBLE POINT PRESSURE (EXPT.) =    3416.70  PSIA


COMPONENT                MOLE FRACTION
---------                -------------
N2                          .00250
H2S                         .27830
CO2                         .03730
METHANE                     .36750
ETHANE                      .07280
PROPANE                     .04210
I-BUTANE                    .00970
N-BUTANE                    .02240
I-PENTANE                   .01030
N-PENTANE                   .01210
HEXANES                     .01890
HEAVY+                      .12610

HEAVY-PLUS:MOLECULAR WEIGHT =    172.
           SPECIFIC GRAVITY =     .81210


CALCULATED BUBBLE POINT PRESSURE =    3406.70  PSIA
```

Table 4.8 Continued

FLASH VAPORIZATION

PRES (PSIA)	TEMP (DEG.F)	SOLN GOR (SCF/STB)	OIL FVF (BBL/STB)	TOTAL FVF (BBL/STB)	DEG API	OIL DENSITY (GM/CC)	Z FACTOR	GAS FVF (CU.FT/SCF)	GAS GRAVITY (AIR=1)	OIL VISC (CP)	GAS VISC (CP)	RELATIVE VOLUME
3406.7	306.0	4358.2	4.195	4.195	194.1	.4346	.000	.0000	.000	.108	.0000	1.000
3206.7	306.0	3237.4	3.360	4.328	176.7	.4592	.764	.0051	1.258	.122	.0358	1.026
3006.7	306.0	2504.8	2.735	4.580	158.9	.4873	.770	.0055	1.184	.136	.0307	1.082
2806.7	306.0	2078.1	2.453	4.876	145.9	.5101	.775	.0060	1.139	.146	.0274	1.149
2606.7	306.0	1774.7	2.248	5.226	135.7	.5295	.781	.0065	1.106	.155	.0250	1.230
2406.7	306.0	1541.7	2.096	5.643	127.5	.5463	.788	.0071	1.081	.163	.0230	1.327
2206.7	306.0	1347.0	1.972	6.150	120.5	.5615	.796	.0078	1.061	.171	.0214	1.445
2006.7	306.0	1178.6	1.866	6.775	114.3	.5757	.805	.0087	1.046	.180	.0201	1.591
1806.7	306.0	1029.3	1.773	7.557	108.7	.5890	.816	.0098	1.035	.189	.0190	1.774
1606.7	306.0	893.6	1.688	8.558	103.6	.6018	.828	.0111	1.027	.198	.0180	2.008
1406.7	306.0	769.7	1.612	9.870	99.0	.6140	.841	.0129	1.022	.208	.0172	2.315
1206.7	306.0	654.1	1.540	11.652	94.6	.6259	.856	.0153	1.021	.219	.0164	2.733
1006.7	306.0	544.5	1.472	14.189	90.4	.6377	.873	.0187	1.023	.232	.0158	3.328
806.7	306.0	438.5	1.405	18.049	86.3	.6496	.890	.0238	1.030	.247	.0152	4.233
606.7	306.0	333.5	1.338	24.554	82.3	.6617	.910	.0324	1.044	.266	.0147	5.759
406.7	306.0	226.1	1.269	37.670	78.2	.6748	.931	.0495	1.064	.293	.0142	8.836
206.7	306.0	110.5	1.191	76.726	73.7	.6896	.955	.0998	1.098	.339	.0138	18.002
14.7	60.0	.0	1.000	769.828	46.9	.7929	.993	.9905	1.079	.430	.0090	184.107

CUMULATIVE RECOVERY DURING DEPLETION (PER MMSCF OF ORIGINAL FLUID)

RESERVOIR PRESSURE (PSIA)	LIQUID VOLUME (%)	GAS PHASE (MSCF)	PLANT PRODUCTS IN GAS PHASE, GALLONS ETHANE	PROPANE	BUTANES	PENTANES+	GPM ETHANE+	PROPANE+	BUTANE+	PENTANE+
3406.7	100.0	.00	0.	0.	0.	0.	.00	.00	.00	.00
3206.7	78.7	23.41	48.	26.	21.	118.	9.07	7.04	5.93	5.03
3006.7	65.7	68.80	141.	76.	61.	282.	8.13	6.08	4.98	4.10
2806.7	58.5	116.33	240.	128.	101.	408.	7.55	5.48	4.38	3.51
2606.7	53.6	165.26	344.	182.	143.	509.	7.12	5.04	3.94	3.08
2406.7	50.0	214.94	450.	236.	185.	590.	6.80	4.70	3.60	2.74
2206.7	47.0	265.52	559.	293.	228.	658.	6.54	4.44	3.34	2.48
2006.7	44.5	316.78	671.	351.	271.	717.	6.35	4.23	3.12	2.26
1806.7	42.3	368.53	787.	411.	317.	771.	6.20	4.07	2.95	2.09
1606.7	40.3	420.69	906.	473.	363.	822.	6.09	3.94	2.82	1.95
1406.7	38.4	472.93	1028.	538.	412.	873.	6.03	3.86	2.72	1.85
1206.7	36.7	525.23	1154.	607.	464.	929.	6.01	3.81	2.65	1.77
1006.7	35.1	577.54	1286.	681.	520.	994.	6.03	3.80	2.62	1.72
806.7	33.5	629.94	1425.	764.	584.	1077.	6.11	3.85	2.64	1.71
606.7	31.9	682.57	1573.	860.	661.	1196.	6.28	3.98	2.72	1.75
406.7	30.2	735.98	1734.	981.	764.	1348.	6.56	4.20	2.87	1.83
206.7	28.4	791.04	1898.	1152.	931.	1602.	7.06	4.66	3.20	2.03
14.7	23.8	858.75	2115.	1440.	1166.	1166.	6.86	4.39	2.72	1.36

DIFFERENTIAL VAPORIZATION

PRES (PSIA)	TEMP (DEG.F)	SOLN GOR (SCF/STB)	OIL FVF (BBL/STB)	TOTAL FVF (BBL/STB)	DEG API	OIL DENSITY (GM/CC)	Z FACTOR	GAS FVF (CU.FT/SCF)	GAS GRAVITY (AIR=1)	OIL VISC (CP)	GAS VISC (CP)	RELATIVE VOLUME
3406.7	306.0	4400.7	4.343	4.343	193.3	.4356	.763	.0048	1.308	.103	.0395	1.000
3206.7	306.0	3453.3	3.763	4.453	183.1	.4498	.769	.0052	1.235	.110	.0347	1.027
3006.7	306.0	2856.2	3.166	4.700	168.6	.4716	.777	.0056	1.159	.121	.0298	1.085
2806.7	306.0	2320.7	2.772	5.000	156.4	.4916	.782	.0060	1.116	.131	.0268	1.154
2606.7	306.0	1932.7	2.493	5.356	146.2	.5096	.784	.0065	1.087	.140	.0246	1.237
2406.7	306.0	1633.6	2.283	5.780	137.6	.5259	.791	.0071	1.067	.149	.0228	1.336
2206.7	306.0	1392.2	2.116	6.292	130.1	.5409	.796	.0078	1.052	.157	.0214	1.454
2006.7	306.0	1190.3	1.979	6.917	123.5	.5549	.802	.0086	1.044	.166	.0201	1.599
1806.7	306.0	1017.0	1.863	7.696	117.6	.5681	.810	.0097	1.040	.175	.0191	1.779
1606.7	306.0	864.9	1.762	8.686	112.2	.5806	.818	.0110	1.041	.184	.0181	2.009
1406.7	306.0	728.8	1.672	9.980	107.3	.5926	.827	.0127	1.047	.194	.0173	2.309
1206.7	306.0	605.2	1.592	11.732	102.7	.6041	.838	.0150	1.059	.204	.0165	2.714
1006.7	306.0	490.8	1.517	14.222	98.5	.6153	.850	.0182	1.078	.217	.0158	3.291
806.7	306.0	382.8	1.447	18.011	94.4	.6263	.864	.0231	1.106	.231	.0151	4.168
606.7	306.0	278.4	1.379	24.414	90.6	.6371	.881	.0314	1.146	.249	.0145	5.650
406.7	306.0	174.3	1.309	37.378	87.0	.6477	.902	.0479	1.204	.274	.0138	8.650
206.7	306.0	67.5	1.235	76.279	83.6	.6577	.931	.0972	1.281	.316	.0132	17.653
14.7	60.0	.0	1.000	776.128	49.9	.7901	.991	.9890	1.160	.366	.0087	179.622

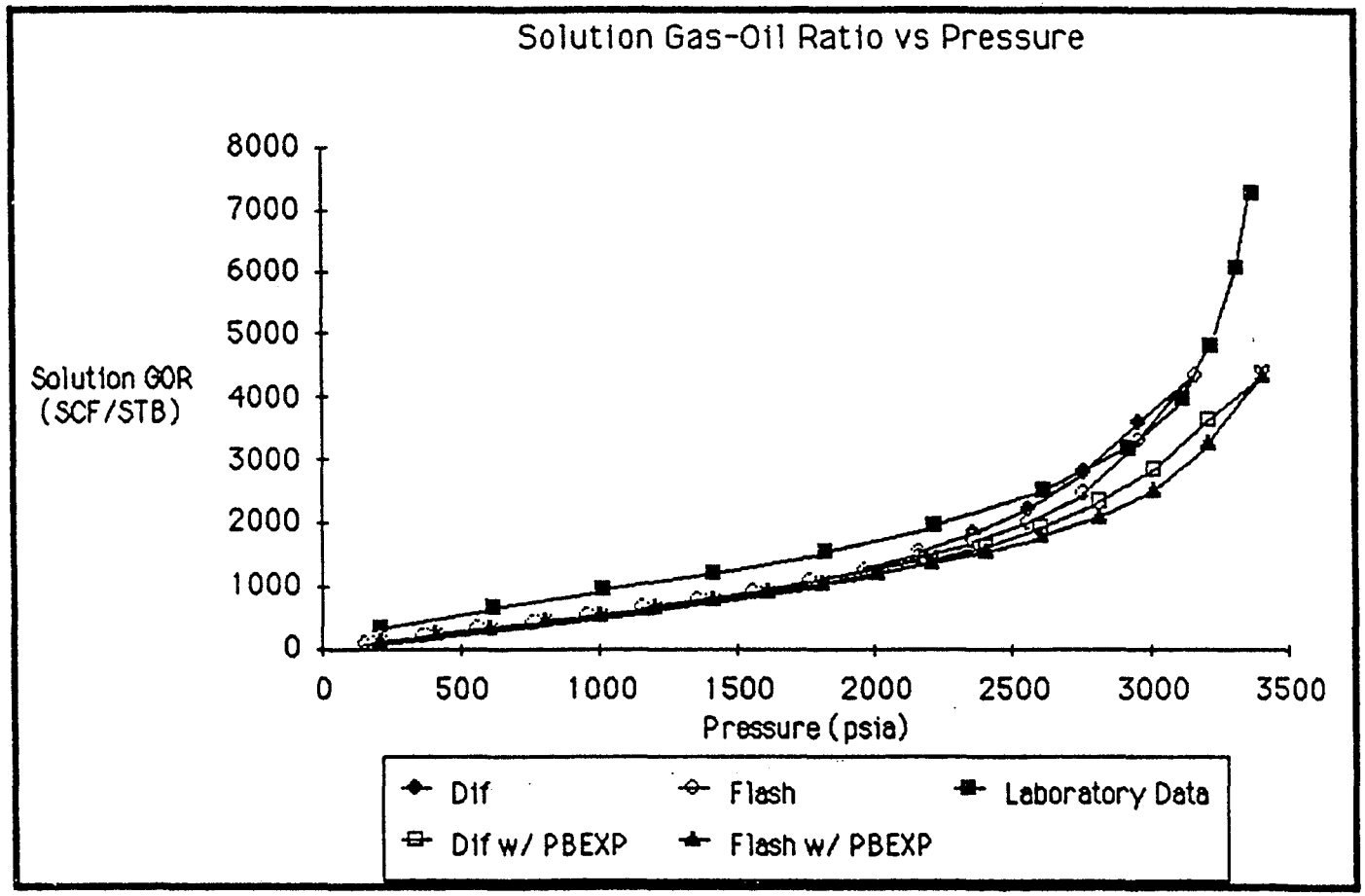

Figure 4.13 Volatile Oil Sample 1, Gas-Oil Ratio

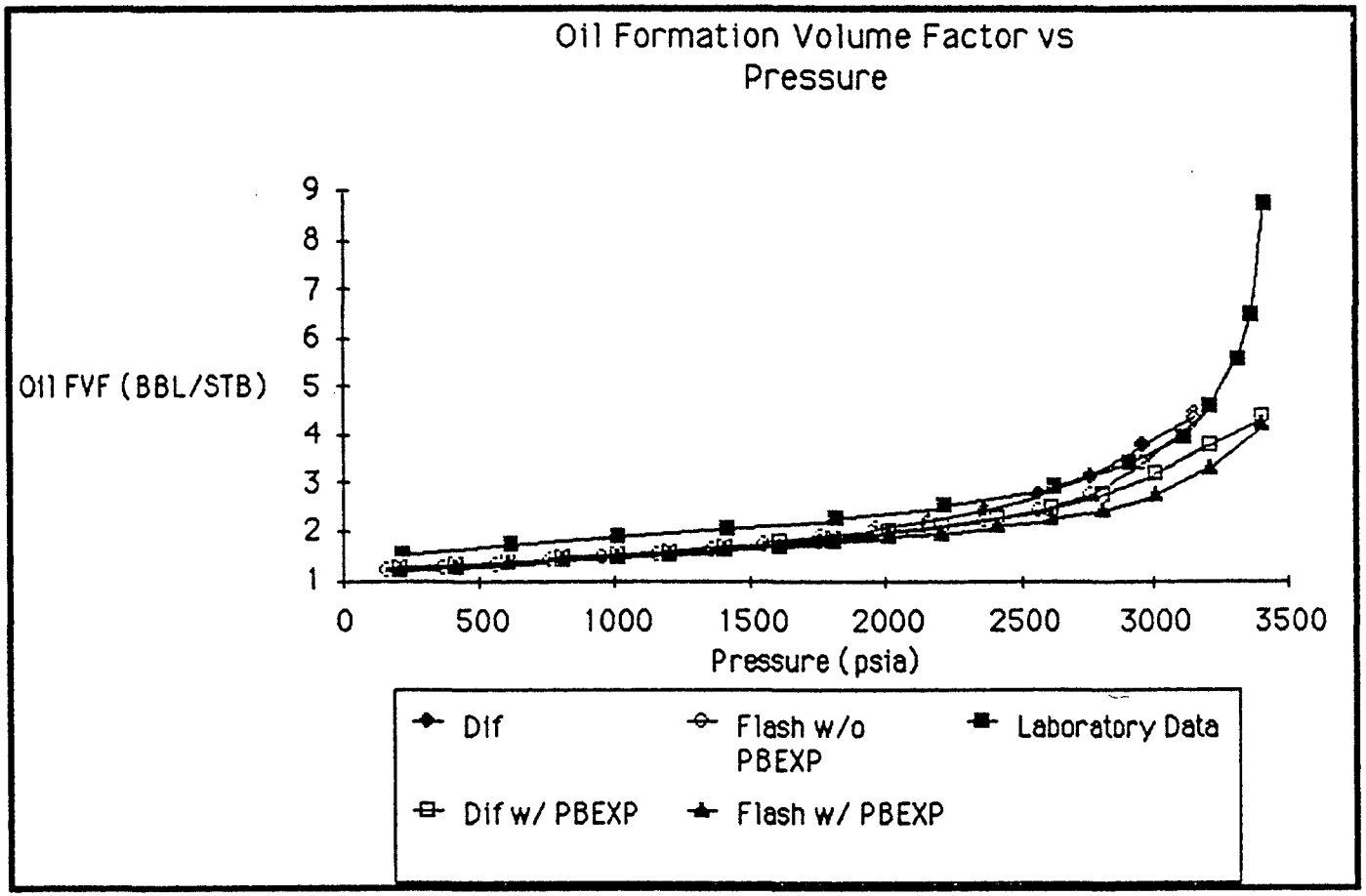

Figure 4.14 Volatile Oil Sample 1, Oil Formation Volume Factor

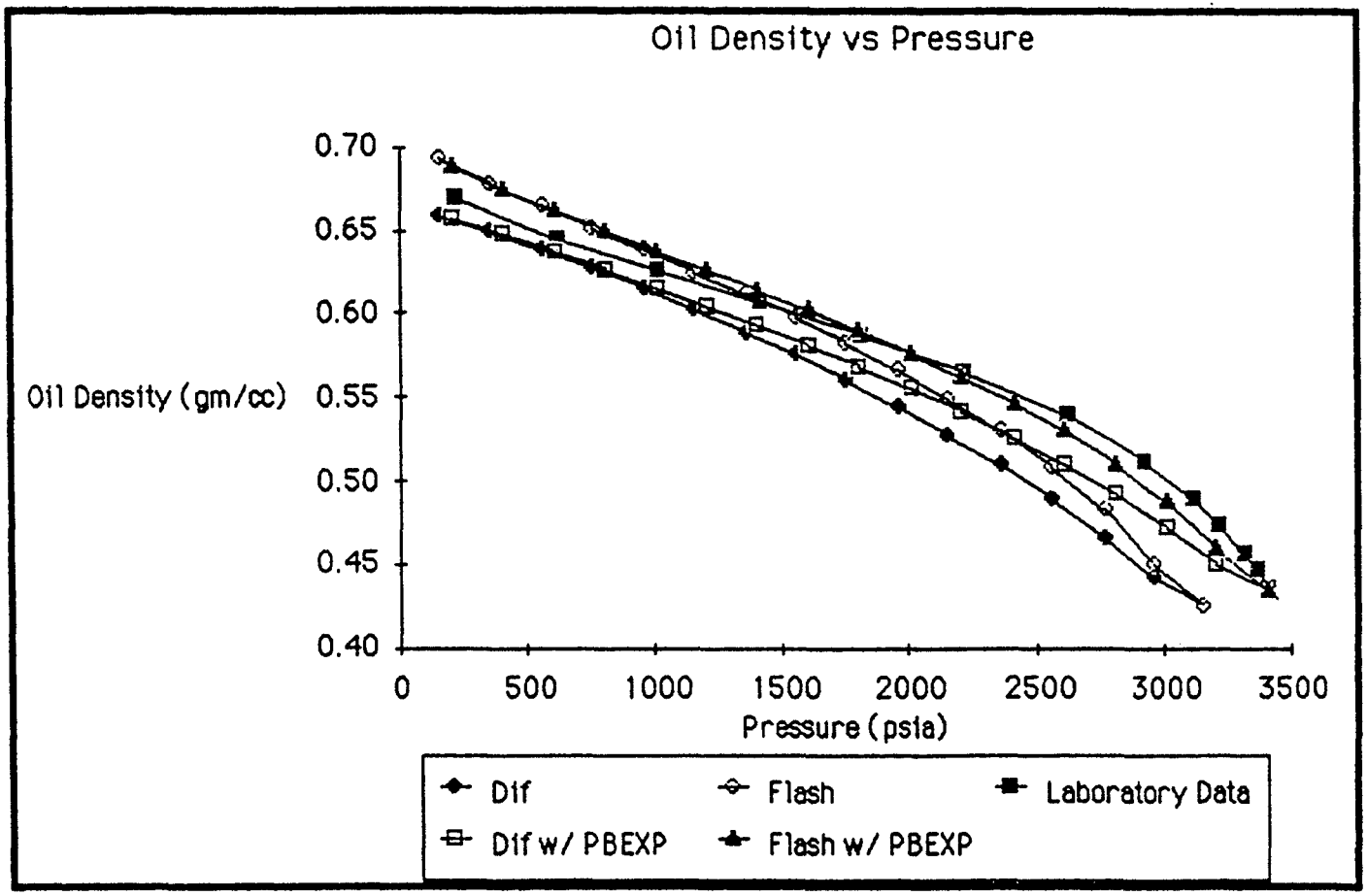

Figure 4.15 Volatile Oil Sample 1, Oil Density

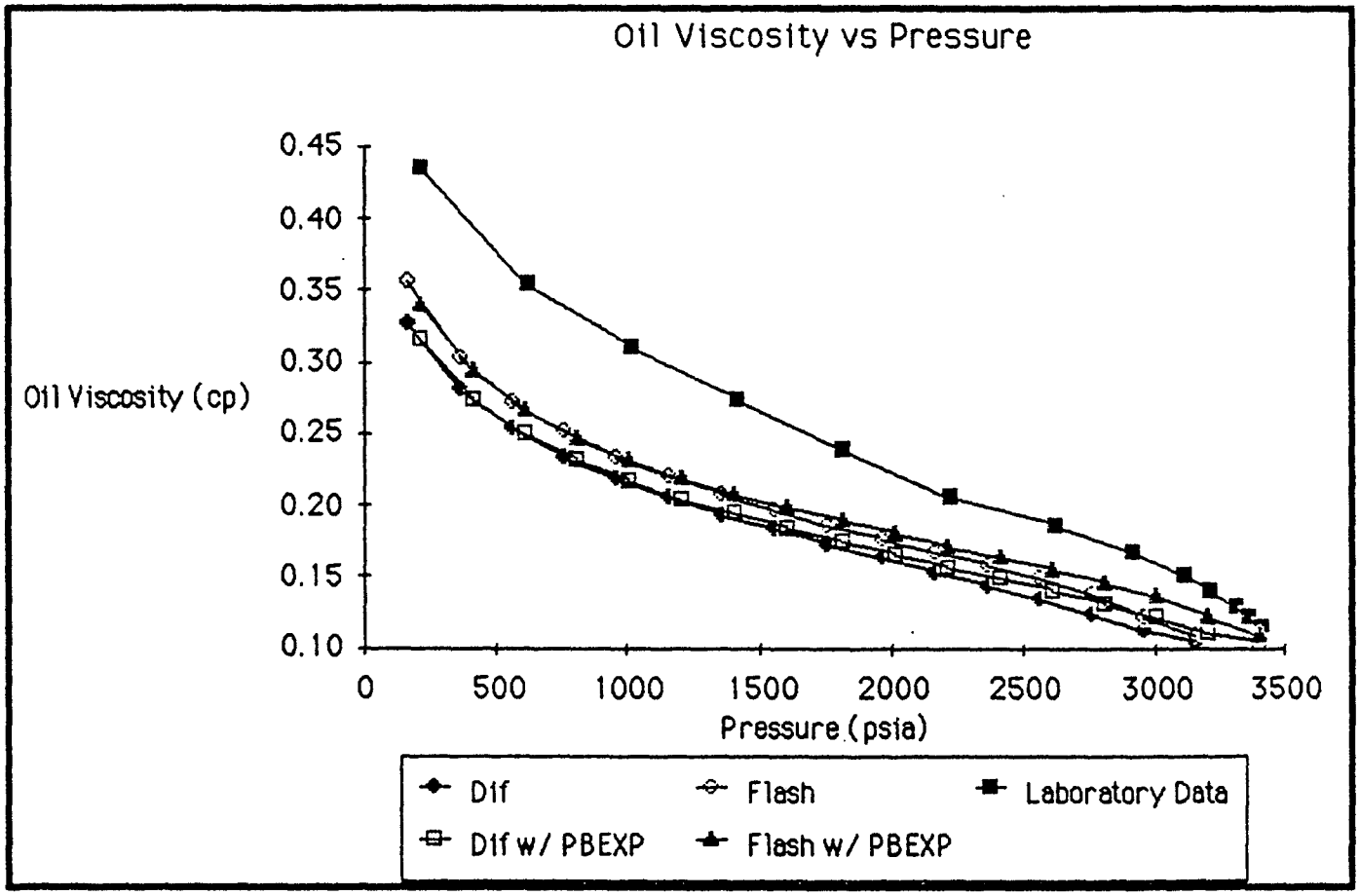

Figure 4.16 Volatile Oil Sample 1, Oil Viscosity

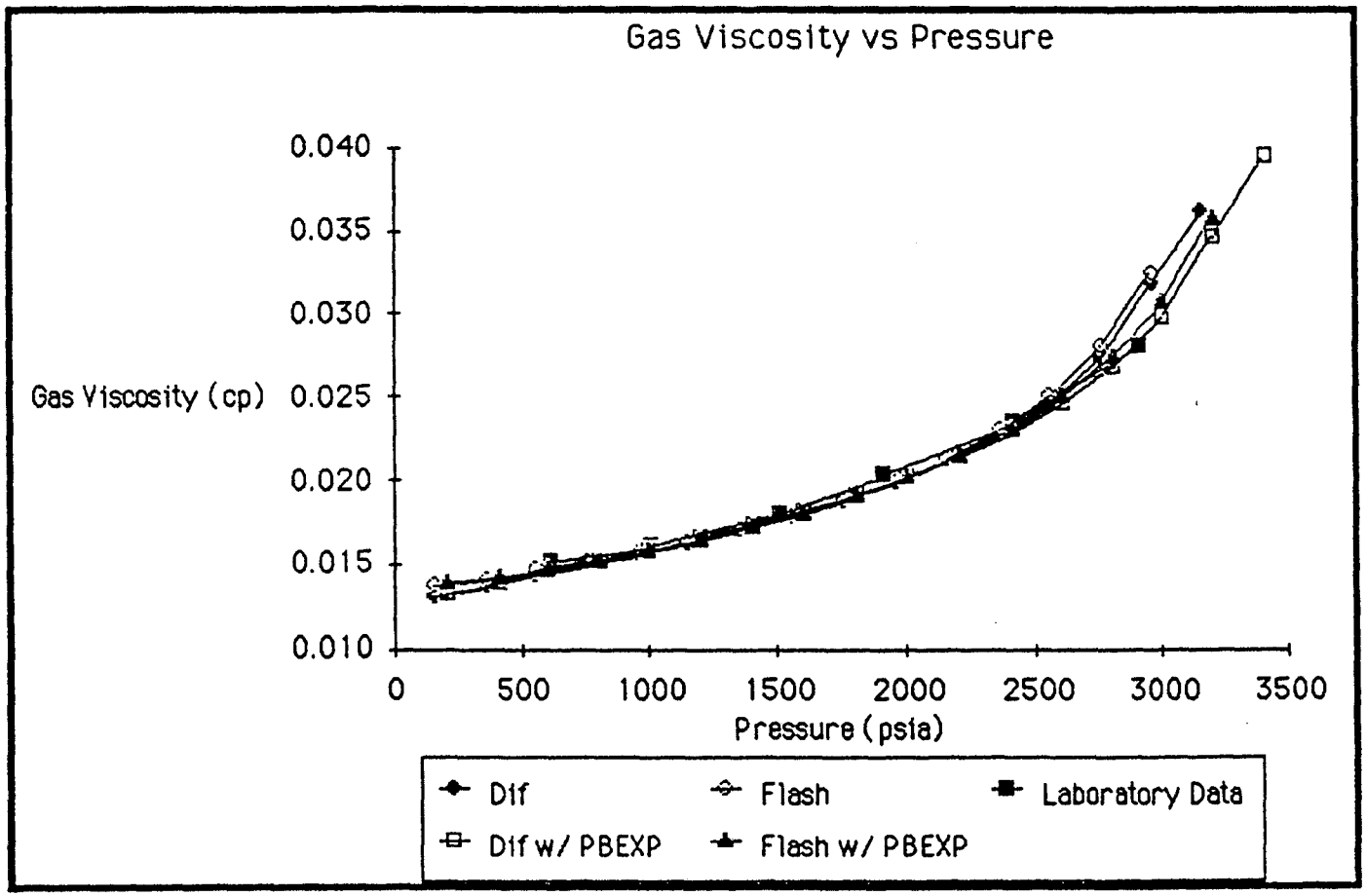

Figure 4.17 Volatile Oil Sample 1, Gas Viscosity

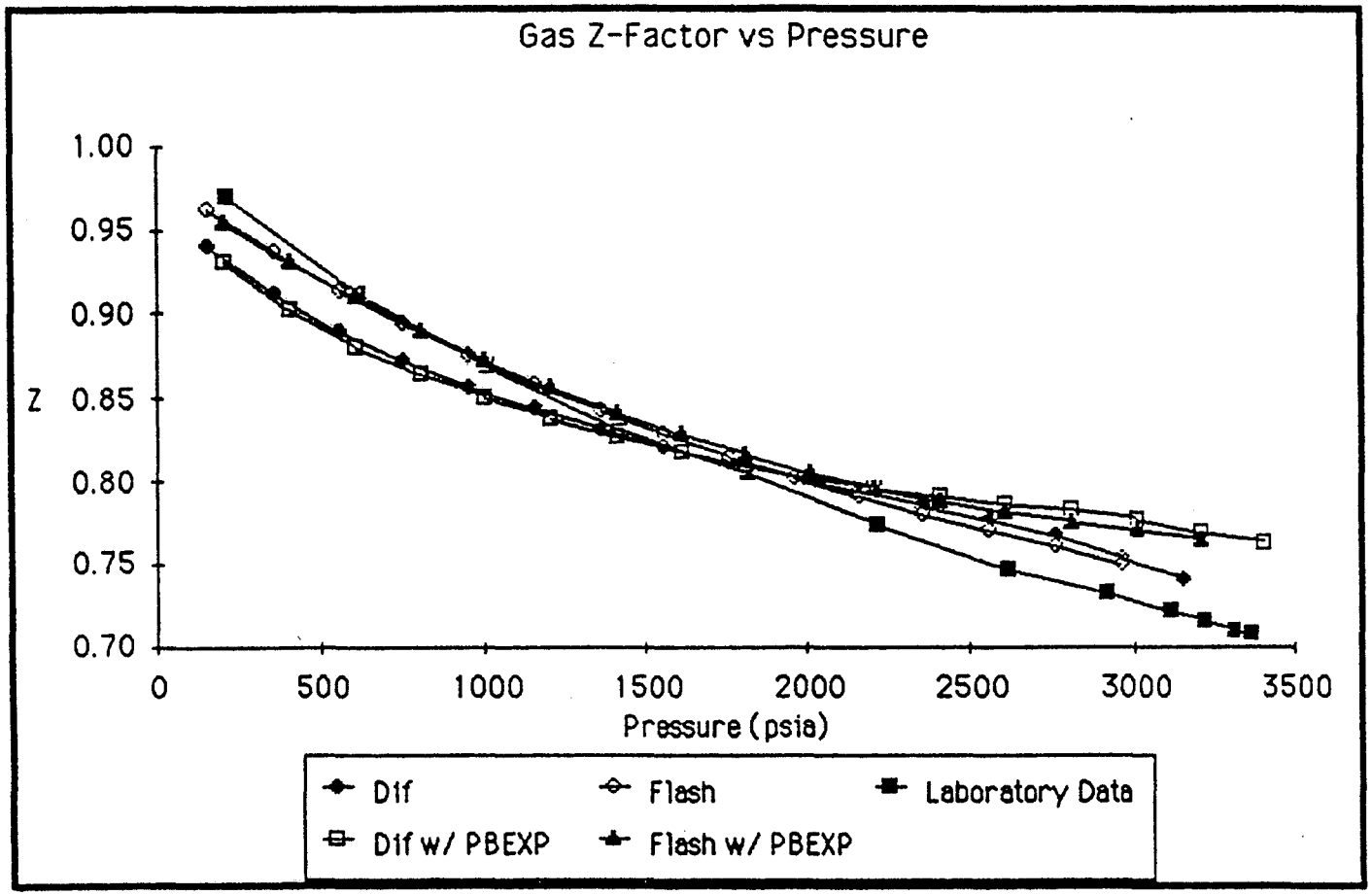

Figure 4.18 Volatile Oil Sample 1, Gas Z-Factor

Table 4.9 Summary of Results for Volatile Oil Sample 1

	Differential Vaporization		Flash Vaporization	
PVT Property	AMPE (%)	AAPE (%)	AMPE (%)	AAPE (%)
Gas-Oil Ratio	41	24.4	35	20.5
with PBEXP	47.3	31.86	40	32.8
Oil FVF	16.4	11.26	17	11.23
with PBEXP	19.5	16.8	27	24.5
Oil Density	13	7.16	12	5.43
with PBEXP	5.6	3.83	2.4	1.33
Oil Viscosity	30.67	28.93	27.14	24.24
with PBEXP	31.03	30	27.14	21.85
Gas Viscosity	3.8	1.26	3.9	1.93
with PBEXP	3.85	1.93	3.94	2.6
Gas Z-Factor	3.4	2.33	3.4	1.77
with PBEXP	7	3.66	6.05	2.8
Average Error		12.56		10.85
with PBEXP		14.68		14.31

Table 4.10 Volatile Oil Sample 2 Output

```
                    ********************************
                    * VOLATILE OIL PVT ANALYSIS *
                    ********************************

ESTIMATED PROPERTIES OF HEAVY-PLUS ARE :

      NORMAL BOILING POINT TEMP. =  475.03  DEG.F
      CRITICAL TEMPERATURE =    802.78  DEG.F
      CRITICAL PRESSURE    =    287.93  PSIA
      ACENTRIC FACTOR      =    .5973

METHOD/CORRELATION USED          PURPOSE
-----------------------          -------
ACCD. SUCCESSIVE SUBSTITUTION    ITERATIVE ESTIMATIO N OF K-VALUES
GRABOWSKI-DAUBERT                N2-H/C,CO2-H/C AND H2S-H/C BINARY
                                 INTERACTION PARAMETERS ESTIMATION

INITIAL RESERVOIR CONDITIONS AND COMPOSITION (GIVEN)
----------------------------------------------------
RESERVOIR TEMPERATURE =    180.0   DEG.F
RESERVOIR PRESSURE    =   5250.00  PSIA
BUBBLE POINT PRESSURE (EXPT.) = NOT GIVEN


COMPONENT                MOLE FRACTION
---------                -------------
N2                          .00400
CO2                         .00370
METHANE                     .61010
ETHANE                      .07470
PROPANE                     .06290
I-BUTANE                    .01010
N-BUTANE                    .02900
I-PENTANE                   .01010
N-PENTANE                   .01240
HEXANES                     .01480
HEAVY+                      .16820

HEAVY-PLUS:MOLECULAR WEIGHT =   198.
           SPECIFIC GRAVITY =    .82940


CALCULATED BUBBLE POINT PRESSURE =   4743.70  PSIA
```

Table 4.10 Continued

FLASH VAPORIZATION

PRES (PSIA)	TEMP (DEG.F)	SOLN GOR (SCF/STD)	OIL FVF (BBL/STD)	TOTAL FVF (BBL/STD)	DEG API	OIL DENSITY (GM/CC)	Z FACTOR	GAS FVF (CU.FT/SCF)	GAS GRAVITY (AIR=1)	OIL VISC (CP)	GAS VISC (CP)	RELATIVE VOLUME
4743.7	180.0	2366.4	2.133	2.133	124.0	.9538	.866	.0000	.000	.191	.0000	1.000
4543.7	180.0	2170.0	1.968	2.152	121.4	.9595	.911	.0034	.838	.196	.0331	1.009
4343.7	180.0	1967.5	1.960	2.194	116.6	.9703	.896	.0037	.819	.207	.0311	1.027
4143.7	180.0	1761.0	1.872	2.241	112.3	.9804	.885	.0038	.802	.217	.0293	1.048
3943.7	180.0	1601.9	1.797	2.295	108.4	.9898	.873	.0040	.788	.227	.0278	1.072
3743.7	180.0	1462.1	1.733	2.352	104.8	.9988	.860	.0041	.775	.237	.0263	1.099
3543.7	180.0	1337.8	1.677	2.419	101.5	1.0074	.850	.0043	.764	.247	.0250	1.129
3343.7	180.0	1223.8	1.626	2.497	98.3	1.0158	.842	.0045	.755	.258	.0238	1.165
3143.7	180.0	1121.4	1.580	2.587	95.3	1.0238	.835	.0048	.746	.269	.0226	1.206
2943.7	180.0	1026.9	1.538	2.692	92.6	1.0316	.830	.0051	.739	.280	.0216	1.254
2743.7	180.0	939.1	1.499	2.816	89.9	1.0392	.826	.0054	.733	.292	.0206	1.311
2543.7	180.0	856.9	1.465	2.965	87.5	1.0466	.823	.0058	.728	.304	.0197	1.380
2343.7	180.0	778.2	1.428	3.145	84.8	1.0541	.821	.0063	.724	.318	.0188	1.465
2143.7	180.0	705.8	1.396	3.366	82.5	1.0613	.820	.0069	.720	.332	.0180	1.565
1943.7	180.0	636.9	1.366	3.642	80.2	1.0685	.819	.0077	.717	.347	.0172	1.692
1743.7	180.0	571.2	1.337	3.992	77.9	1.0758	.819	.0088	.715	.364	.0165	1.854
1543.7	180.0	508.4	1.309	4.448	75.8	1.0827	.819	.0098	.714	.383	.0159	2.065
1343.7	180.0	448.1	1.281	5.056	73.6	1.0898	.820	.0110	.713	.403	.0153	2.347
1143.7	180.0	390.1	1.255	5.900	71.5	1.0970	.865	.0137	.713	.426	.0148	2.737
943.7	180.0	333.5	1.230	7.129	69.4	1.1042	.881	.0168	.713	.454	.0143	3.307
743.7	180.0	279.0	1.205	9.053	67.4	1.1114	.899	.0210	.715	.485	.0139	4.199
543.7	180.0	224.8	1.179	12.454	65.3	1.1189	.919	.0305	.719	.525	.0135	5.774
343.7	180.0	169.6	1.152	19.949	63.2	1.1268	.941	.0498	.726	.574	.0132	9.229
143.7	180.0	107.6	1.120	48.563	60.8	1.1359	.966	.1213	.744	.636	.0128	22.462
14.7	60.0	.0	1.000	467.917	44.8	1.2935	.996	.9933	.816	.949	.0099	191.869

CUMULATIVE RECOVERY DURING DEPLETION (PER MSCF OF ORIGINAL FLUID)

RESERVOIR PRESSURE (PSIA)	LIQUID VOLUME (%)	GAS PHASE (MSCF)	PLANT PRODUCTS IN GAS PHASE, GALLONS ETHANE	PROPANE	BUTANES	PENTANES+	GPM ETHANE+	PROPANE+	BUTANE+	PENTANE+
4743.7	100.0	.00	0.	0.	0.	0.	.00	.00	.00	.00
4543.7	97.0	9.78	17.	13.	8.	11.	4.22	4.29	2.94	2.14
4343.7	91.9	24.91	47.	40.	24.	34.	4.22	4.29	2.91	1.91
4143.7	87.8	41.22	80.	68.	40.	58.	4.23	4.30	2.90	1.71
3943.7	84.3	73.54	141.	98.	70.	113.	5.57	3.65	2.33	1.54
3743.7	81.3	97.06	186.	129.	92.	155.	5.41	3.49	2.17	1.39
3543.7	78.6	121.77	234.	161.	94.	193.	5.27	3.35	2.03	1.26
3343.7	76.2	147.09	284.	195.	112.	169.	5.18	3.23	1.91	1.14
3143.7	74.1	175.99	337.	231.	133.	163.	5.05	3.13	1.81	1.04
2943.7	72.1	203.65	393.	269.	154.	195.	4.96	3.03	1.71	.96
2743.7	70.3	233.16	452.	308.	176.	206.	4.89	2.95	1.63	.88
2543.7	68.6	264.92	514.	349.	198.	216.	4.83	2.88	1.57	.82
2343.7	67.0	297.87	581.	393.	222.	227.	4.78	2.83	1.51	.76
2143.7	65.5	331.84	650.	439.	244.	237.	4.74	2.78	1.46	.72
1943.7	64.0	367.10	724.	486.	272.	248.	4.71	2.74	1.42	.68
1743.7	62.7	403.54	801.	537.	298.	260.	4.70	2.71	1.38	.66
1543.7	61.4	441.02	884.	590.	325.	272.	4.70	2.69	1.35	.62
1343.7	60.1	479.34	971.	644.	353.	284.	4.71	2.68	1.33	.60
1143.7	58.9	518.31	1060.	700.	383.	300.	4.74	2.68	1.32	.58
943.7	57.7	557.82	1165.	771.	418.	316.	4.79	2.69	1.31	.57
743.7	56.5	597.65	1283.	845.	449.	333.	4.87	2.72	1.31	.56
543.7	55.3	637.48	1418.	934.	490.	356.	4.93	2.79	1.33	.56
343.7	54.0	676.11	1590.	1058.	545.	384.	5.27	2.92	1.37	.57
143.7	52.5	721.20	1854.	1260.	647.	434.	5.83	3.26	1.50	.60
14.7	44.9	782.68	2418.	2197.	1096.	581.	7.92	4.83	2.14	.74

DIFFERENTIAL VAPORIZATION

PRES (PSIA)	TEMP (DEG.F)	SOLN GOR (SCF/STD)	OIL FVF (BBL/STD)	TOTAL FVF (BBL/STD)	DEG API	OIL DENSITY (GM/CC)	Z FACTOR	GAS FVF (CU.FT/SCF)	GAS GRAVITY (AIR=1)	OIL VISC (CP)	GAS VISC (CP)	RELATIVE VOLUME
4743.7	180.0	2143.7	1.958	1.958	124.0	.9538	.866	.0000	.000	.191	.0000	1.000
4543.7	180.0	2020.5	1.933	2.118	121.4	.9595	.911	.0034	.838	.196	.0336	1.009
4343.7	180.0	1812.1	1.733	2.154	117.1	.9692	.897	.0037	.815	.206	.0310	1.028
4143.7	180.0	1635.5	1.650	2.198	113.1	.9786	.884	.0038	.797	.216	.0291	1.049
3943.7	180.0	1488.2	1.776	2.248	109.3	.9876	.873	.0040	.781	.227	.0275	1.073
3743.7	180.0	1342.5	1.712	2.305	105.9	.9962	.862	.0042	.768	.239	.0261	1.101
3543.7	180.0	1219.0	1.656	2.370	102.6	1.0044	.853	.0043	.756	.250	.0247	1.132
3343.7	180.0	1107.2	1.605	2.445	99.6	1.0124	.845	.0046	.745	.264	.0235	1.168
3143.7	180.0	1004.9	1.559	2.533	96.7	1.0202	.839	.0048	.736	.277	.0224	1.210
2943.7	180.0	911.0	1.516	2.636	93.9	1.0277	.834	.0051	.729	.292	.0214	1.259
2743.7	180.0	823.8	1.476	2.758	91.3	1.0352	.830	.0055	.722	.307	.0204	1.318
2543.7	180.0	742.9	1.439	2.904	88.8	1.0426	.828	.0059	.716	.323	.0195	1.388
2343.7	180.0	667.1	1.405	3.080	86.4	1.0499	.826	.0064	.712	.340	.0186	1.472
2143.7	180.0	595.7	1.373	3.296	84.0	1.0566	.825	.0070	.708	.358	.0179	1.576
1943.7	180.0	528.6	1.343	3.565	81.8	1.0635	.825	.0077	.705	.377	.0171	1.704
1743.7	180.0	464.9	1.312	3.905	79.6	1.0704	.826	.0087	.704	.399	.0165	1.867
1543.7	180.0	404.6	1.285	4.344	77.4	1.0772	.828	.0099	.704	.421	.0158	2.077
1343.7	180.0	348.0	1.259	4.920	75.4	1.0840	.830	.0113	.707	.447	.0153	2.357
1143.7	180.0	291.8	1.233	5.733	73.4	1.0907	.834	.0134	.711	.477	.0148	2.742
943.7	180.0	239.2	1.209	6.898	71.4	1.0974	.877	.0168	.719	.507	.0143	3.300
743.7	180.0	188.7	1.186	8.715	69.5	1.1040	.891	.0216	.734	.545	.0138	4.169
543.7	180.0	140.1	1.162	11.981	67.6	1.1106	.907	.0301	.759	.587	.0134	5.695
343.7	180.0	93.2	1.139	18.846	65.8	1.1171	.923	.0485	.809	.644	.0128	9.019
143.7	180.0	47.6	1.113	45.267	64.1	1.1233	.941	.1182	.934	.674	.0121	21.656
14.7	60.0	.0	1.000	376.610	49.4	1.2822	.996	.9839	1.344	.888	.0082	180.268

Table 4.11 Volatile Oil Sample 2 Output with Experimental Bubble Point Given

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                    ******************************
                    * VOLATILE OIL PVT ANALYSIS *
                    ******************************

ESTIMATED PROPERTIES OF HEAVY-PLUS ARE :

      NORMAL BOILING POINT TEMP. =  475.03  DEG.F
      CRITICAL TEMPERATURE =    802.78  DEG.F
      CRITICAL PRESSURE    =    287.93  PSIA
      ACENTRIC FACTOR      =    .5973

METHOD/CORRELATION USED          PURPOSE
-----------------------          -------
ACCD. SUCCESSIVE SUBSTITUTION    ITERATIVE ESTIMATIO N OF K-VALUES
GRABOWSKI-DAUBERT                N2-H/C,CO2-H/C AND H2S-H/C BINARY
                                 INTERACTION PARAMETERS ESTIMATION

INITIAL RESERVOIR CONDITIONS AND COMPOSITION (GIVEN)
----------------------------------------------------
RESERVOIR TEMPERATURE =    180.0   DEG.F
RESERVOIR PRESSURE    =    5264.70  PSIA
BUBBLE POINT PRESSURE (EXPT.) =    5092.70  PSIA


COMPONENT                MOLE FRACTION
---------                -------------
N2                          .00400
CO2                         .00370
METHANE                     .61010
ETHANE                      .07470
PROPANE                     .06290
I-BUTANE                    .01010
N-BUTANE                    .02900
I-PENTANE                   .01010
N-PENTANE                   .01240
HEXANES                     .01480
HEAVY+                      .16820

HEAVY-PLUS:MOLECULAR WEIGHT =    198.
           SPECIFIC GRAVITY =     .82940


CALCULATED BUBBLE POINT PRESSURE =    5047.70  PSIA
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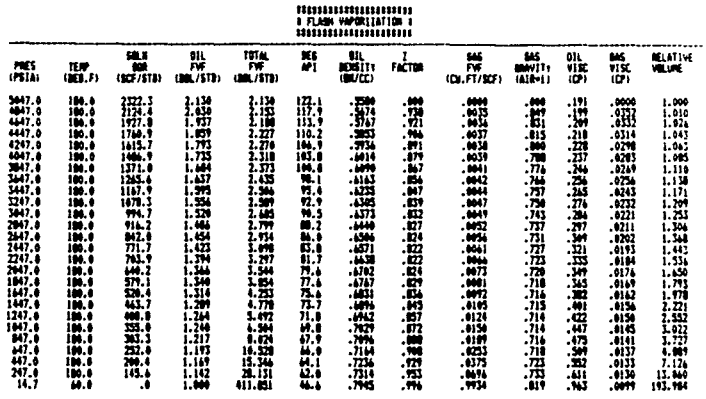
Table 4.11 Continued



0 FLASH VAPORIZATION 0

PRES (PSIA)	TEMP (DEG.F)	SOLN GOR (SCF/STB)	OIL FVF (BBL/STB)	TOTAL FVF (BBL/STB)	DEG API	OIL DENSITY (GM/CC)	Z FACTOR	GAS FVF (CU.FT/SCF)	GAS GRAVITY (AIR=1)	OIL VISC (CP)	GAS VISC (CP)	RELATIVE VOLUME
5047.0	180.0	2222.3	1.136	1.136	122.1	.9388	.888	.0008	.888	.191	.0000	1.000
4847.0	180.0	2156.4	1.150	1.150	117.9	.9424	.900	.0008	.857	.199	.0000	1.010
4647.0	180.0	1927.8	1.158	1.158	111.9	.9367	.911	.0036	.851	.207	.0333	1.026
4447.0	180.0	1760.9	1.859	2.227	110.2	.9833	.984	.0037	.815	.218	.0314	1.043
4247.0	180.0	1615.7	1.793	2.278	106.9	.9734	.991	.0038	.808	.228	.0298	1.061
4047.0	180.0	1486.9	1.733	2.318	105.8	.9614	.979	.0039	.788	.237	.0283	1.085
3847.0	180.0	1371.8	1.684	2.373	106.8	.9698	.967	.0041	.776	.246	.0269	1.110
3647.0	180.0	1265.6	1.637	2.435	98.1	.9163	.956	.0042	.766	.256	.0256	1.138
3447.0	180.0	1167.9	1.595	2.504	97.4	.9233	.967	.0044	.757	.265	.0245	1.171
3247.0	180.0	1078.3	1.556	2.589	92.9	.9305	.959	.0047	.750	.276	.0232	1.209
3047.0	180.0	994.7	1.520	2.665	90.5	.9373	.953	.0049	.743	.284	.0221	1.253
2847.0	180.0	916.2	1.488	2.799	88.2	.9440	.957	.0052	.737	.297	.0211	1.306
2647.0	180.0	842.0	1.454	2.914	84.0	.9306	.924	.0054	.731	.309	.0202	1.368
2447.0	180.0	771.7	1.423	3.098	83.8	.9371	.933	.0061	.727	.321	.0193	1.443
2247.0	180.0	705.9	1.394	3.297	81.7	.9438	.933	.0066	.723	.335	.0184	1.536
2047.0	180.0	644.2	1.365	3.544	79.6	.9702	.924	.0073	.720	.349	.0176	1.650
1847.0	180.0	579.1	1.340	3.854	77.6	.9767	.924	.0081	.718	.365	.0169	1.793
1647.0	180.0	529.4	1.316	4.252	75.6	.9832	.924	.0093	.716	.388	.0162	1.978
1447.0	180.0	483.7	1.289	4.778	73.7	.9894	.934	.0105	.715	.401	.0156	2.221
1247.0	180.0	440.8	1.264	5.472	71.8	.9842	.957	.0124	.714	.422	.0150	2.552
1047.0	180.0	355.0	1.240	6.504	69.8	.9629	.972	.0150	.714	.447	.0145	3.022
847.0	180.0	305.3	1.217	8.024	67.9	.9708	.988	.0189	.716	.475	.0141	3.727
647.0	180.0	252.0	1.193	10.520	66.0	.9784	.988	.0253	.718	.508	.0137	4.909
447.0	180.0	200.4	1.169	15.346	64.1	.9236	.929	.0375	.723	.552	.0133	7.126
247.0	180.0	145.6	1.142	28.151	62.0	.9314	.935	.0696	.733	.611	.0130	13.960
14.7	60.0	.0	1.000	411.851	44.6	.7965	.995	.9934	.819	.963	.0099	193.984

CUMULATIVE RECOVERY DURING DEPLETION (PER MSCF OF ORIGINAL FLUID)

RESERVOIR PRESSURE (PSIA)	LIQUID VOLUME (%)	GAS PHASE (MSCF)	PLANT PRODUCTS IN GAS PHASE, GALLONS ETHANE	PROPANE	BUTANES	PENTANES+	GPM ETHANE+	PROPANE+	BUTANE+	PENTANE+
5047.7	100.0	.00	0.	0.	0.	0.	.00	.00	.00	.00
4847.7	99.3	11.34	2.	1.	1.	0.	6.38	4.47	3.10	2.27
4647.7	98.5	24.28	7.	3.	2.	1.	6.14	4.23	2.87	2.05
4447.7	97.5	37.20	11.	5.	3.	1.	5.94	4.03	2.67	1.86
4247.7	96.2	50.79	15.	7.	4.	2.	5.76	3.86	2.49	1.69
4047.7	94.5	67.26	19.	10.	5.	2.	5.59	3.68	2.33	1.53
3847.7	92.1	88.07	24.	13.	7.	3.	5.45	3.54	2.19	1.40
3647.7	89.1	111.55	30.	17.	9.	4.	5.33	3.41	2.07	1.28
3447.7	85.4	139.71	37.	21.	11.	5.	5.23	3.29	1.96	1.17
3247.7	81.1	180.95	48.	27.	14.	6.	5.11	3.19	1.86	1.08
3047.7	75.4	207.52	55.	31.	16.	7.	5.03	3.10	1.77	.99
2847.7	69.0	235.46	63.	35.	18.	8.	4.95	3.02	1.69	.92
2647.7	66.3	264.00	71.	39.	20.	9.	4.95	2.95	1.62	.85
2447.7	64.8	293.32	79.	44.	22.	10.	4.84	2.89	1.56	.80
2247.7	63.5	327.79	88.	49.	25.	11.	4.80	2.84	1.51	.76
2047.7	62.2	361.16	97.	54.	27.	12.	4.77	2.80	1.47	.71
1847.7	60.9	395.79	106.	59.	30.	13.	4.75	2.77	1.43	.66
1647.7	61.7	431.54	116.	65.	33.	14.	4.74	2.74	1.40	.65
1447.7	66.5	466.24	125.	70.	35.	15.	4.74	2.73	1.37	.62
1247.7	70.4	505.79	136.	76.	38.	16.	4.74	2.72	1.35	.60
1047.7	70.2	543.04	146.	82.	41.	17.	4.79	2.72	1.34	.59
847.7	77.1	583.17	157.	88.	44.	18.	4.85	2.74	1.34	.58
647.7	86.0	630.83	169.	95.	47.	19.	4.90	2.78	1.34	.58
447.7	98.9	659.08	177.	99.	49.	20.	5.13	2.86	1.36	.57
247.7	151.6	700.11	188.	105.	52.	21.	5.40	3.05	1.43	.59
14.7	97.0	785.34	211.	118.	58.	23.	7.96	4.99	2.20	.77

0 DIFFERENTIAL VAPORIZATION 0

PRES (PSIA)	TEMP (DEG.F)	SOLN GOR (SCF/STB)	OIL FVF (BBL/STB)	TOTAL FVF (BBL/STB)	DEG API	OIL DENSITY (GM/CC)	Z FACTOR	GAS FVF (CU.FT/SCF)	GAS GRAVITY (AIR=1)	OIL VISC (CP)	GAS VISC (CP)	RELATIVE VOLUME
5047.7	180.0	2142.1	1.107	1.107	122.1	.9388	.888	.0008	.888	.191	.0000	1.000
4847.7	180.0	1940.7	1.085	1.085	117.9	.9424	.900	.0008	.857	.199	.0000	1.010
4647.7	180.0	1776.1	1.067	1.067	114.6	.9384	.913	.0036	.851	.207	.0333	1.026
4447.7	180.0	1612.9	1.052	2.178	111.0	.9833	.984	.0037	.809	.218	.0313	1.044
4247.7	180.0	1470.7	1.760	2.219	107.7	.9734	.992	.0038	.793	.228	.0298	1.064
4047.7	180.0	1343.2	1.707	2.265	104.7	.9790	.980	.0039	.788	.238	.0283	1.086
3847.7	180.0	1230.0	1.658	2.316	101.9	.9843	.969	.0041	.766	.247	.0268	1.112
3647.7	180.0	1122.9	1.607	2.370	99.2	.9136	.957	.0042	.757	.257	.0253	1.141
3447.7	180.0	1026.6	1.564	2.440	96.6	.9203	.968	.0045	.747	.267	.0240	1.174
3247.7	180.0	937.0	1.524	2.529	94.2	.9270	.960	.0047	.738	.277	.0229	1.212
3047.7	180.0	854.0	1.487	2.612	91.8	.9337	.957	.0049	.731	.290	.0219	1.257
2847.7	180.0	776.1	1.452	2.735	89.5	.9403	.961	.0053	.724	.299	.0209	1.311
2647.7	180.0	703.3	1.420	2.866	87.3	.9468	.965	.0057	.719	.302	.0199	1.376
2447.7	180.0	636.5	1.390	3.008	85.2	.9530	.969	.0061	.714	.315	.0191	1.453
2247.7	180.0	568.6	1.360	3.233	83.1	.9591	.969	.0067	.710	.329	.0183	1.547
2047.7	180.0	507.3	1.333	3.466	81.1	.9650	.969	.0073	.707	.344	.0175	1.663
1847.7	180.0	446.0	1.307	3.766	79.1	.9710	.969	.0082	.705	.361	.0168	1.808
1647.7	180.0	392.0	1.281	4.151	77.2	.9701	.969	.0093	.705	.380	.0162	1.993
1447.7	180.0	338.0	1.257	4.656	75.3	.9643	.969	.0106	.704	.402	.0156	2.234
1247.7	180.0	288.1	1.234	5.338	73.4	.9585	.969	.0124	.709	.425	.0150	2.564
1047.7	180.0	234.3	1.211	6.297	71.6	.9587	.979	.0150	.715	.455	.0145	3.025
847.7	180.0	188.3	1.189	7.731	69.8	.9588	.989	.0188	.727	.488	.0141	3.714
647.7	180.0	141.9	1.167	10.000	68.1	.9790	.998	.0250	.746	.529	.0136	4.843
447.7	180.0	97.0	1.146	14.366	66.4	.9731	.994	.0366	.781	.585	.0131	6.998
247.7	180.0	53.3	1.123	26.366	64.7	.9711	.993	.0679	.854	.696	.0125	12.671
14.7	60.0	.0	1.000	374.510	49.6	.7814	.987	.9843	1.324	.798	.0083	180.965

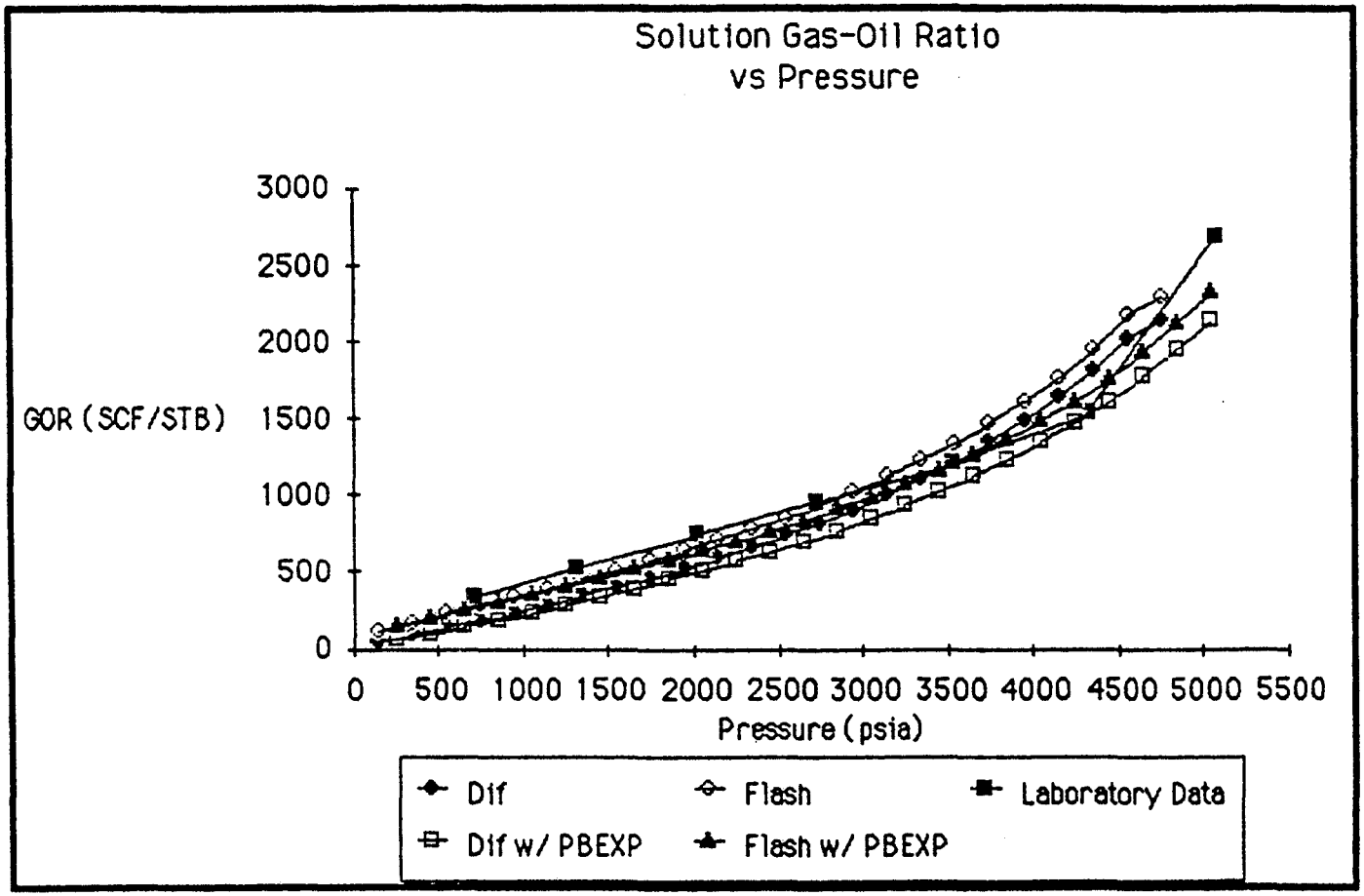


Figure 4.19 Volatile Oil Sample 2, Gas-Oil Ratio

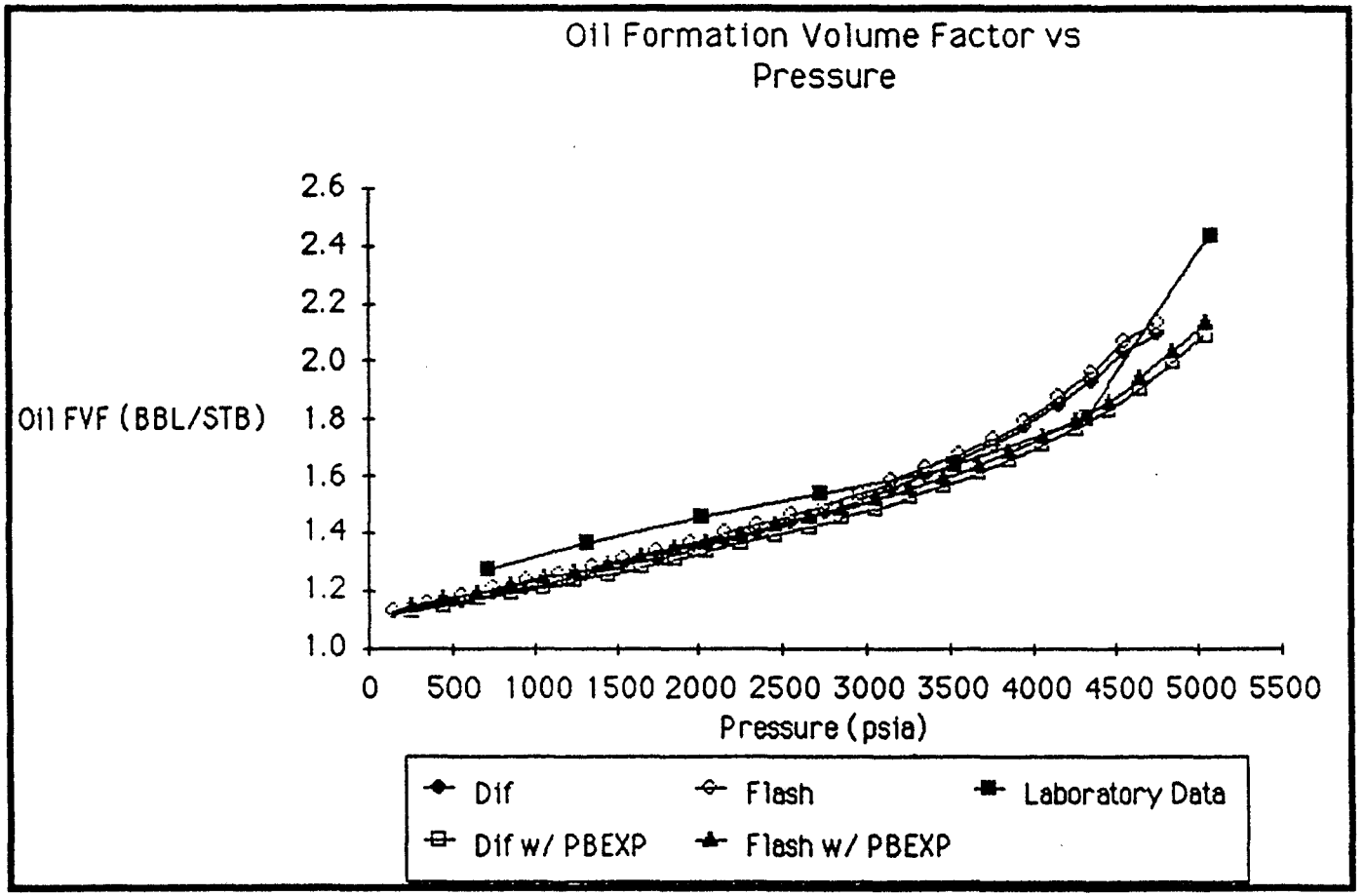


Figure 4.20 Volatile Oil Sample 2, Oil Formation Volume Factor

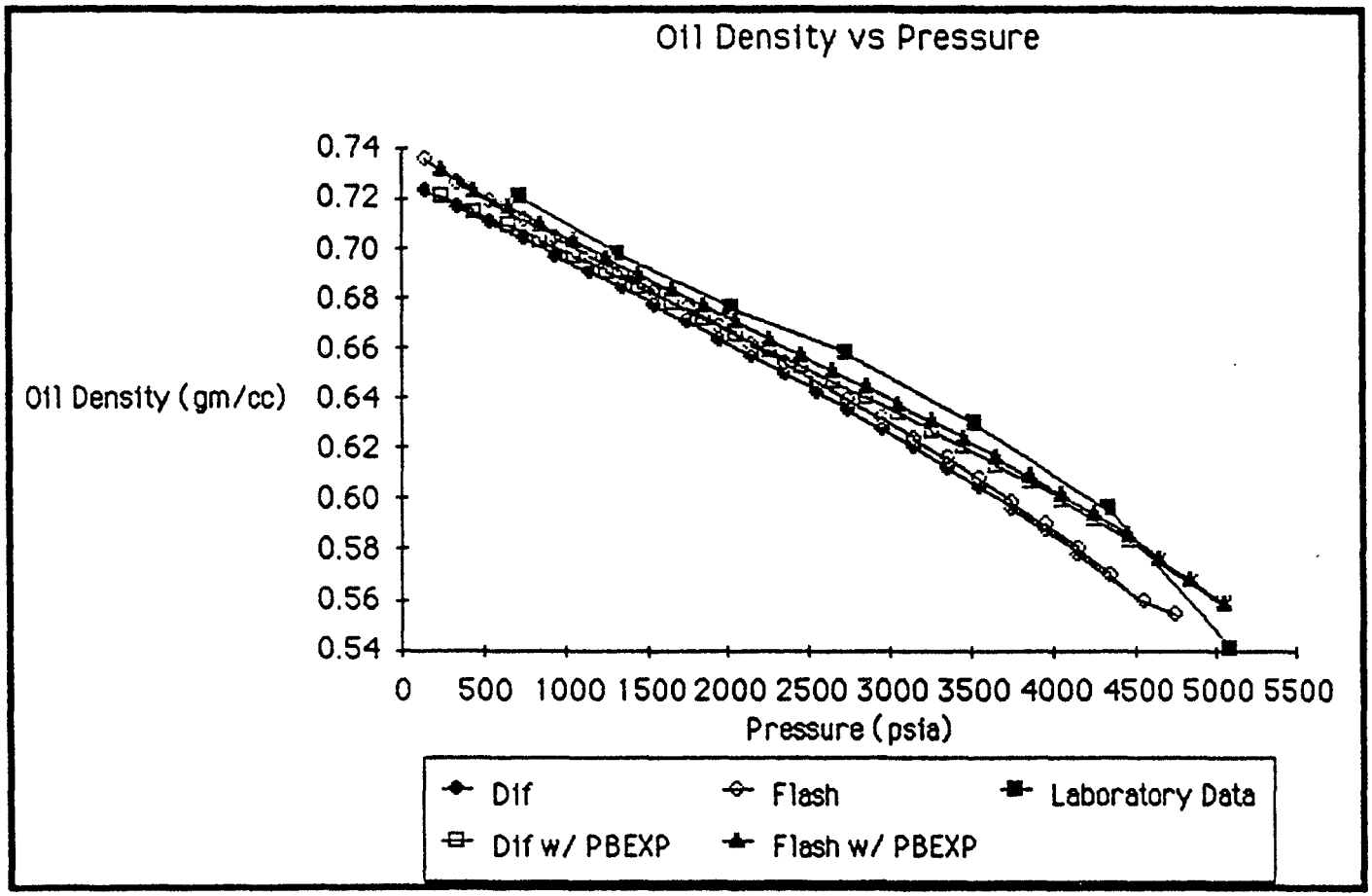


Figure 4.21 Volatile Oil Sample 2, Oil Density

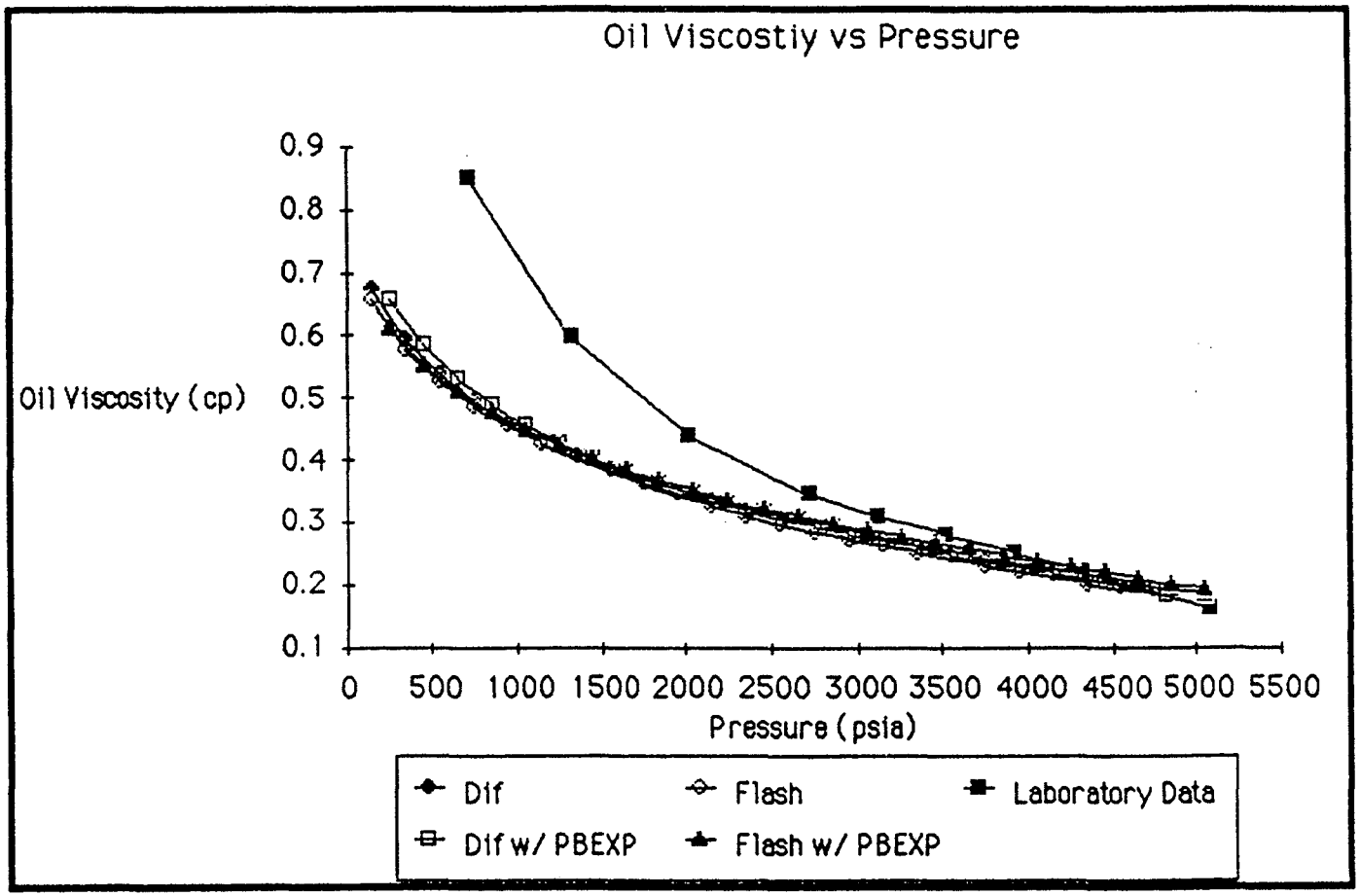


Figure 4.22 Volatile Oil Sample 2, Oil Viscosity

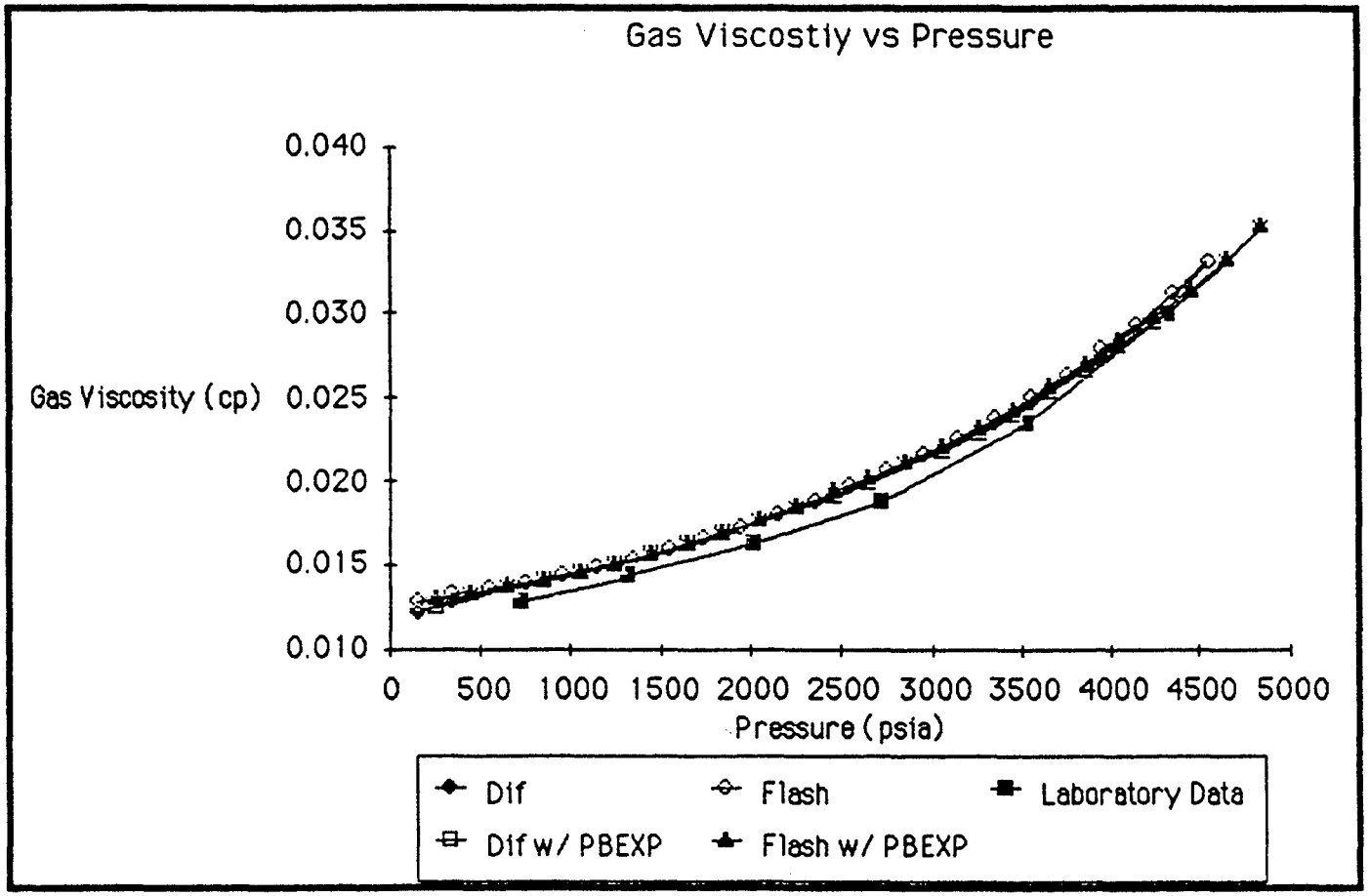


Figure 4.23 Volatile Oil Sample 2, Gas Viscosity

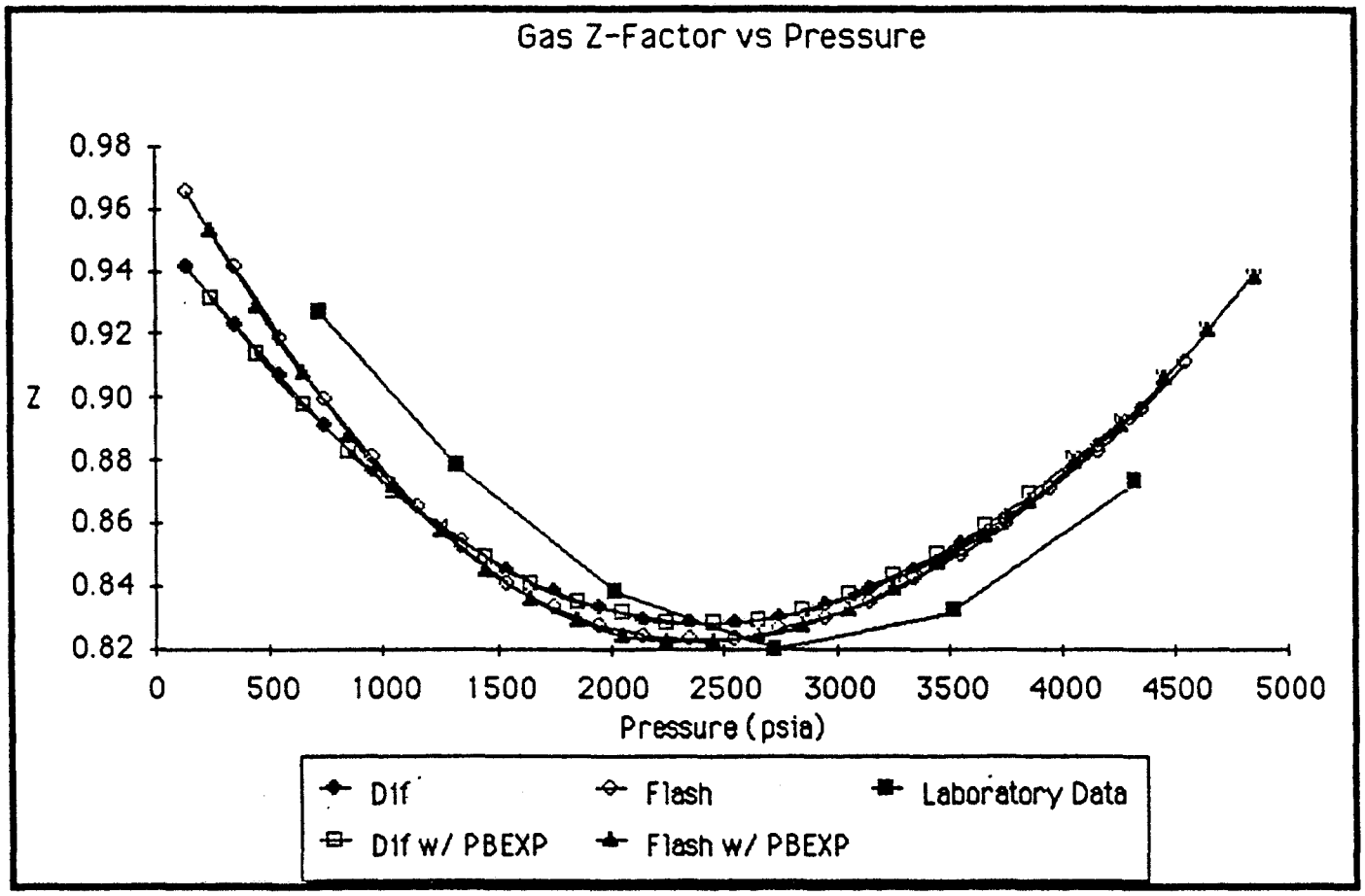


Figure 4.24 Volatile Oil Sample 2, Gas Z-Factor

Table 4.12 Summary of Results for Volatile Oil Sample 2

	Differential Vaporization		Flash Vaporization	
PVT Property	AMPE (%)	AAPE (%)	AMPE (%)	AAPE (%)
Gas-Oil Ratio	35	20.75	17.8	9.85
with PBEXP	46.3	25.54	19.5	11.86
Oil FVF	7.6	4.78	6.1	4.21
with PBEXP	11.8	7.42	10.1	6.38
Oil Density	5.3	3.4	5.3	2.69
with PBEXP	2	1.55	1.5	0.7
Oil Viscosity	36.1	25.5	36.5	25.6
with PBEXP	36.1	25.5	36.5	25.6
Gas Viscosity	7.3	5.5	7.4	5.68
with PBEXP	7.3	5.5	7.4	5.68
Gas Z-Factor	2.7	2.07	3.1	2.08
with PBEXP	3.4	1.92	3.1	1.87
Average Error		10.33		8.35
with PBEXP		11.24		8.68

4.4 Gas Condensate Samples

Gas condensate sample 1 had a laboratory measured dew point pressure of 4014.7 psia. The program calculated the dew point pressure to be 3293.7 psia, an error of 17.97%. Gas condensate sample 2 had a laboratory measured dew point pressure of 5174.7 psia. The program calculated the dew point pressure to be 3449.9 psia, an error of 33.33%.

Gas condensate sample 1 had improved calculated values near the dew point when the experimental dew point pressure was supplied, while gas condensate sample 2 had much improved values over all pressures when the experimental dew point pressure was supplied.

The output for the gas condensate samples are given in Tables 4.13, 4.14, 4.16, and 4.17. The results are presented graphically in Figures 4.25 through 4.32 and compared numerically in Tables 4.15 and 4.18.

The output in Table 4.13 includes the results of a typical multistage separator calculation.

Table 4.13 Gas Condensate Sample 1 Output

```
          ****************************************
          * RETROGRADE CONDENSATE PVT ANALYSIS *
          ****************************************

METHOD/CORRELATION USED          PURPOSE
-----------------------          -------


ESTIMATED PROPERTIES OF HEAVY-PLUS ARE :

      NORMAL BOILING POINT TEMP. =  337.58  DEG.F
      CRITICAL TEMPERATURE =    672.74  DEG.F
      CRITICAL PRESSURE    =    375.11  PSIA
      ACENTRIC FACTOR      =    .4362
ACCD. SUCCESSIVE SUBSTITUTION    ITERATIVE ESTIMATION OF K-VALUES
GRABOWSKI-DAUBERT                N2-H/C,CO2-H/C AND H2S-H/C BINARY
                                 INTERACTION PARAMETERS ESTIMATION

INITIAL RESERVOIR CONDITIONS AND COMPOSITION (GIVEN)
---------------------------------------------------
RESERVOIR TEMPERATURE =    186.0   DEG.F
RESERVOIR PRESSURE    =   5727.40  PSIA
FIRST DEW POINT PRESSURE (EXPT) = NOT GIVEN


COMPONENT                MOLE FRACTION
---------                -------------
N2                          .00130
CO2                         .00180
METHANE                     .61920
ETHANE                      .14080
PROPANE                     .08350
I-BUTANE                    .00970
N-BUTANE                    .03410
I-PENTANE                   .00840
N-PENTANE                   .01480
HEXANES                     .01790
HEAVY+                      .06850

HEAVY-PLUS:MOLECULAR WEIGHT =    143.
           SPECIFIC GRAVITY =    .79500


EST.DEW POINT PRESSURE (NEMETH-KENNEDY CORRELATION)  =     3542.33  PSIA

CALCULATED FIRST DEW POINT PRESSURE =     3293.10  PSIA

CALCULATED SECOND DEW POINT PRESSURE =      19.70  PSIA
```

Table 4.13 Continued

CONSTANT VOLUME DEPLETION STUDY

PRESSURE (PSIA)	TEMP (DEG.F)	CUMULATIVE RETROGRADE CONDENSATION (%)	RELATIVE VOLUME	CUMULATIVE GAS PRODUCED (% VOL)	GAS FVF (CU.FT/SCF)	GAS Z FACTOR	GAS GRAVITY (AIR=1)	GAS VISCOSITY (CP)	LIQUID DENSITY (GM/CC)
3293.1	186.0	.00	1.000	.00	.0040	.7202	1.157	.0428	.0000
3193.1	186.0	31.25	1.036	33.62	.0041	.7233	1.068	.0359	.4165
3093.1	186.0	33.22	1.074	37.83	.0043	.7266	1.014	.0320	.4417
2993.1	186.0	33.09	1.111	39.80	.0044	.7275	.981	.0295	.4586
2893.1	186.0	32.43	1.151	41.31	.0046	.7285	.955	.0276	.4734
2793.1	186.0	31.78	1.195	42.92	.0048	.7300	.933	.0260	.4864
2693.1	186.0	31.08	1.243	44.54	.0050	.7318	.915	.0246	.4981
2593.1	186.0	30.37	1.294	46.20	.0052	.7339	.900	.0234	.5090
2493.1	186.0	29.68	1.351	47.94	.0054	.7365	.887	.0223	.5192
2393.1	186.0	29.00	1.413	49.77	.0056	.7397	.875	.0214	.5288
2293.1	186.0	28.34	1.482	51.65	.0059	.7432	.865	.0206	.5379
2193.1	186.0	27.66	1.558	53.58	.0062	.7474	.856	.0198	.5469
2093.1	186.0	27.05	1.643	55.60	.0065	.7521	.848	.0191	.5552
1993.1	186.0	26.43	1.738	57.66	.0069	.7573	.841	.0184	.5633
1893.1	186.0	25.84	1.844	59.77	.0073	.7632	.835	.0178	.5711
1793.1	186.0	25.26	1.963	61.93	.0078	.7698	.830	.0173	.5788
1693.1	186.0	24.70	2.099	64.12	.0084	.7770	.826	.0168	.5863
1593.1	186.0	24.15	2.253	66.33	.0090	.7848	.822	.0163	.5936
1493.1	186.0	23.59	2.430	68.55	.0097	.7933	.819	.0159	.6011
1393.1	186.0	23.08	2.634	70.80	.0105	.8025	.817	.0155	.6081
1293.1	186.0	22.57	2.872	73.04	.0114	.8123	.815	.0151	.6151
1193.1	186.0	22.08	3.153	75.29	.0126	.8227	.814	.0148	.6220
1093.1	186.0	21.59	3.488	77.52	.0139	.8338	.813	.0145	.6289
993.1	186.0	21.12	3.894	79.74	.0155	.8456	.813	.0142	.6358
893.1	186.0	20.65	4.393	81.94	.0175	.8579	.814	.0139	.6426
793.1	186.0	20.19	5.021	84.11	.0200	.8709	.816	.0136	.6495
693.1	186.0	19.73	5.835	86.24	.0232	.8844	.819	.0134	.6565
593.1	186.0	19.27	6.928	88.35	.0276	.8985	.824	.0132	.6636
493.1	186.0	18.79	8.470	90.41	.0337	.9133	.830	.0130	.6710
393.1	186.0	18.29	10.805	92.44	.0430	.9288	.839	.0128	.6789
293.1	186.0	17.71	14.744	94.42	.0587	.9450	.854	.0125	.6879
193.1	186.0	16.94	22.781	96.35	.0908	.9620	.883	.0123	.6994
93.1	186.0	15.54	48.145	98.25	.1918	.9802	.960	.0119	.7189
14.7	60.0	14.31	248.632	99.66	.9905	.9929	.979	.0093	.7641

Table 4.13 Continued

CALCULATED RECOVERY DURING DEPLETION
(PER MMSCF OF ORIGINAL FLUID)

PRESSURE (PSIA)	GAS PHASE (MSCF)	PLANT PRODUCTS IN GAS PHASE, GALLONS				GPM			
		ETHANE	PROPANE	BUTANES	PENTANES+	ETHANE+	PROPANE+	BUTANE+	PENTANE+
3293.1	.00	0.	0.	0.	0.	12.91	9.15	6.86	5.47
3193.1	336.21	1261.	746.	438.	1465.	11.63	7.88	5.66	4.36
3093.1	378.29	1418.	822.	473.	1391.	10.85	7.10	4.93	3.68
2993.1	397.96	1492.	854.	484.	1297.	10.37	6.62	4.48	3.26
2893.1	413.14	1549.	878.	492.	1214.	10.00	6.25	4.13	2.94
2793.1	429.20	1611.	904.	502.	1144.	9.69	5.94	3.83	2.67
2693.1	445.38	1673.	932.	512.	1086.	9.44	5.68	3.59	2.44
2593.1	461.96	1737.	961.	524.	1037.	9.22	5.46	3.38	2.24
2493.1	479.41	1805.	993.	537.	995.	9.03	5.27	3.19	2.08
2393.1	497.66	1877.	1026.	551.	958.	8.87	5.09	3.03	1.92
2293.1	516.49	1952.	1062.	566.	927.	8.72	4.95	2.89	1.79
2193.1	535.78	2029.	1099.	582.	900.	8.60	4.82	2.77	1.68
2093.1	556.01	2111.	1138.	599.	876.	8.50	4.70	2.65	1.58
1993.1	576.61	2195.	1179.	616.	858.	8.41	4.60	2.56	1.49
1893.1	597.73	2282.	1222.	635.	841.	8.33	4.51	2.47	1.41
1793.1	619.28	2373.	1266.	654.	827.	8.27	4.44	2.39	1.34
1693.1	641.16	2467.	1312.	674.	816.	8.22	4.37	2.32	1.27
1593.1	663.27	2563.	1359.	695.	808.	8.18	4.31	2.27	1.22
1493.1	685.52	2663.	1408.	716.	802.	8.15	4.27	2.21	1.17
1393.1	707.96	2766.	1460.	738.	799.	8.14	4.23	2.17	1.13
1293.1	730.44	2873.	1513.	761.	798.	8.14	4.21	2.14	1.09
1193.1	752.89	2984.	1568.	786.	800.	8.15	4.19	2.11	1.06
1093.1	775.23	3100.	1627.	811.	805.	8.18	4.18	2.08	1.04
993.1	797.41	3221.	1689.	837.	812.	8.22	4.19	2.07	1.02
893.1	819.37	3349.	1755.	866.	823.	8.29	4.20	2.06	1.00
793.1	841.06	3485.	1827.	896.	837.	8.38	4.23	2.06	1.00
693.1	862.44	3634.	1907.	931.	857.	8.50	4.28	2.07	.99
593.1	883.47	3798.	2000.	970.	882.	8.66	4.36	2.10	1.00
493.1	904.12	3986.	2110.	1018.	910.	8.87	4.47	2.13	1.01
393.1	924.37	4209.	2252.	1080.	946.	9.18	4.63	2.19	1.02
293.1	944.18	4492.	2455.	1172.	1000.	9.66	4.90	2.30	1.06
193.1	963.54	4871.	2808.	1347.	1104.	10.51	5.46	2.54	1.15
93.1	982.46	5257.	3613.	1891.	1495.	12.48	7.12	3.45	1.52
14.7	996.55	5461.	4091.	2150.	1421.	13.17	7.69	3.58	1.43

Table 4.13 Continued

MULTI-STAGE SEPARATOR CALCULATIONS

SEPARATOR PRESSURE (PSIG)	TEMP. (DEG.F)	GAS/OIL RATIO (1)	GAS/OIL RATIO (2)	TANK OIL GRAVITY (DEG.API)	FORMATION VOLUME FACTOR(3)	SEPARATOR VOLUME FACTOR(4)	GAS GRAVITY
485.3	70.	4124.	5718.			1.387	.728
35.3	70.	582.	2764.			1.064	1.170
.0	60.	129.	901.	57.5	1.387	.981	1.630

NOTE

(1) GOR IN SCF/BBL
(2) GOR IN SCF/STB
(3) BBLS OF OIL AT SATURATION PRESSURE PER STB
(4) BBLS OF OIL AT GIVEN P&T PER STB

Table 4.14 Gas Condensate Sample 1 Output with Experimental Dew Point Given

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          ****************************************
          * RETROGRADE CONDENSATE PVT ANALYSIS *
          ****************************************

METHOD/CORRELATION USED          PURPOSE
-----------------------          -------

ESTIMATED PROPERTIES OF HEAVY-PLUS ARE :

      NORMAL BOILING POINT TEMP. =  337.58  DEG.F
      CRITICAL TEMPERATURE =    672.74  DEG.F
      CRITICAL PRESSURE    =    375.11  PSIA
      ACENTRIC FACTOR      =    .4362
ACCD. SUCCESSIVE SUBSTITUTION    ITERATIVE ESTIMATION OF K-VALUES
GRABOWSKI-DAUBERT                N2-H/C,CO2-H/C AND H2S-H/C BINARY
                                 INTERACTION PARAMETERS ESTIMATION

INITIAL RESERVOIR CONDITIONS AND COMPOSITION (GIVEN)
---------------------------------------------------
RESERVOIR TEMPERATURE =    186.0   DEG.F
RESERVOIR PRESSURE    =    5727.40  PSIA
FIRST DEW POINT PRESSURE (EXPT) =    4014.70  PSIA

COMPONENT                MOLE FRACTION
---------                -------------
N2                          .00130
CO2                         .00180
METHANE                     .61920
ETHANE                      .14080
PROPANE                     .08350
I-BUTANE                    .00970
N-BUTANE                    .03410
I-PENTANE                   .00840
N-PENTANE                   .01480
HEXANES                     .01790
HEAVY+                      .06850

HEAVY-PLUS:MOLECULAR WEIGHT =    143.
           SPECIFIC GRAVITY =     .79500


EST.DEW POINT PRESSURE (NEMETH-KENNEDY CORRELATION)  =     3542.33  PSIA

CALCULATED FIRST DEW POINT PRESSURE =     3888.10  PSIA

CALCULATED SECOND DEW POINT PRESSURE =      19.70  PSIA
```

Table 4.14 Continued

****
* CONSTANT VOLUME DEPLETION STUDY *

PRESSURE (PSIA)	TEMP (DEG.F)	CUMULATIVE RETROGRADE CONDENSATION (%)	RELATIVE VOLUME	CUMULATIVE GAS PRODUCED (% VOL)	GAS FVF (CU.FT/SCF)	GAS Z FACTOR	GAS GRAVITY (AIR=1)	GAS VISCOSITY (CP)	LIQUID DENSITY (GM/CC)
3888.1	186.0	.00	1.000	.00	.0038	.8018	1.156	.0477	.4200
3788.1	186.0	18.86	1.015	20.04	.0038	.7927	1.099	.0427	.4493
3688.1	186.0	26.46	1.034	28.91	.0039	.7867	1.053	.0387	.4701
3588.1	186.0	25.77	1.051	29.40	.0039	.7779	1.034	.0368	.4869
3488.1	186.0	27.37	1.074	32.36	.0040	.7723	1.006	.0344	.4974
3388.1	186.0	27.48	1.097	33.87	.0041	.7662	.988	.0327	.5069
3288.1	186.0	27.82	1.123	35.73	.0042	.7614	.969	.0310	.5153
3188.1	186.0	27.92	1.152	37.41	.0043	.7571	.953	.0295	.5232
3088.1	186.0	27.93	1.183	39.10	.0044	.7535	.938	.0281	.5306
2988.1	186.0	27.88	1.218	40.80	.0046	.7507	.925	.0269	.5376
2888.1	186.0	27.86	1.258	42.65	.0047	.7491	.911	.0257	.5441
2788.1	186.0	27.61	1.299	44.28	.0049	.7469	.901	.0246	.5506
2688.1	186.0	27.42	1.346	46.08	.0051	.7461	.890	.0236	.5567
2588.1	186.0	27.18	1.398	47.90	.0053	.7459	.881	.0227	.5628
2488.1	186.0	26.92	1.455	49.77	.0055	.7464	.872	.0219	.5686
2388.1	186.0	26.63	1.518	51.68	.0057	.7477	.864	.0211	.5743
2288.1	186.0	26.33	1.589	53.63	.0060	.7497	.857	.0203	.5799
2188.1	186.0	26.00	1.668	55.62	.0063	.7524	.850	.0196	.5855
2088.1	186.0	25.67	1.756	57.66	.0066	.7559	.844	.0190	.5910
1988.1	186.0	25.33	1.854	59.73	.0070	.7602	.839	.0184	.5963
1888.1	186.0	24.97	1.966	61.83	.0074	.7653	.834	.0178	.6016
1788.1	186.0	24.61	2.092	63.96	.0079	.7712	.830	.0173	.6069
1688.1	186.0	24.25	2.235	66.10	.0084	.7779	.826	.0168	.6122
1588.1	186.0	23.89	2.398	68.26	.0090	.7853	.823	.0163	.6174
1488.1	186.0	23.51	2.586	70.42	.0097	.7935	.820	.0159	.6227
1388.1	186.0	23.14	2.804	72.59	.0105	.8025	.818	.0155	.6279
1288.1	186.0	22.77	3.058	74.75	.0115	.8123	.817	.0151	.6331
1188.1	186.0	22.40	3.358	76.89	.0126	.8227	.816	.0148	.6383
1088.1	186.0	22.03	3.717	79.02	.0140	.8339	.815	.0144	.6435
988.1	186.0	21.66	4.151	81.13	.0156	.8457	.815	.0141	.6487
888.1	186.0	21.29	4.686	83.20	.0176	.8582	.816	.0139	.6541
788.1	186.0	20.92	5.362	85.25	.0201	.8713	.818	.0136	.6595
688.1	186.0	20.53	6.237	87.26	.0234	.8850	.820	.0134	.6651
588.1	186.0	20.14	7.416	89.23	.0279	.8993	.824	.0132	.6709
488.1	186.0	19.73	9.084	91.16	.0341	.9143	.830	.0129	.6770
388.1	186.0	19.27	11.620	93.05	.0437	.9299	.838	.0127	.6837
288.1	186.0	18.73	15.927	94.90	.0598	.9462	.852	.0125	.6916
188.1	186.0	17.94	24.833	96.70	.0933	.9632	.881	.0123	.7026
88.1	186.0	16.40	54.020	98.45	.2029	.9813	.963	.0119	.7229
14.7	60.0	15.19	263.668	99.68	.9905	.9929	.978	.0093	.7666

Table 4.14 Continued

CALCULATED RECOVERY DURING DEPLETION
(PER MMSCF OF ORIGINAL FLUID)

PRESSURE (PSIA)	GAS PHASE (MSCF)	PLANT PRODUCTS IN GAS PHASE, GALLONS ETHANE	PROPANE	BUTANES	PENTANES+	GPM ETHANE+	PROPANE+	BUTANE+	PENTANE+
3888.1	.00	0.	0.	0.	0.	12.88	9.13	6.84	5.45
3788.1	200.42	751.	451.	268.	950.	12.07	8.33	6.08	4.74
3688.1	289.06	1081.	640.	376.	1203.	11.42	7.68	5.46	4.16
3588.1	294.04	1101.	648.	378.	1154.	11.16	7.41	5.21	3.92
3488.1	323.64	1211.	707.	409.	1153.	10.75	7.01	4.83	3.56
3388.1	338.68	1268.	736.	423.	1132.	10.51	6.76	4.59	3.34
3288.1	357.29	1338.	771.	440.	1108.	10.24	6.49	4.33	3.10
3188.1	374.10	1402.	804.	456.	1084.	10.01	6.26	4.12	2.90
3088.1	390.97	1466.	836.	471.	1060.	9.80	6.05	3.91	2.71
2988.1	408.03	1531.	868.	486.	1035.	9.61	5.86	3.73	2.54
2888.1	426.48	1601.	903.	502.	1009.	9.42	5.66	3.54	2.37
2788.1	442.78	1664.	935.	517.	990.	9.27	5.51	3.40	2.24
2688.1	460.79	1734.	969.	533.	969.	9.12	5.36	3.26	2.10
2588.1	478.99	1804.	1004.	549.	949.	8.99	5.22	3.13	1.98
2488.1	497.67	1878.	1040.	566.	931.	8.87	5.10	3.01	1.87
2388.1	516.78	1953.	1077.	582.	914.	8.76	4.98	2.90	1.77
2288.1	536.32	2030.	1116.	600.	898.	8.66	4.87	2.79	1.67
2188.1	556.25	2110.	1155.	618.	884.	8.57	4.77	2.70	1.59
2088.1	576.60	2193.	1195.	636.	871.	8.49	4.69	2.61	1.51
1988.1	597.31	2277.	1237.	654.	860.	8.42	4.61	2.54	1.44
1888.1	618.31	2364.	1279.	673.	850.	8.36	4.53	2.46	1.38
1788.1	639.57	2454.	1323.	693.	842.	8.31	4.47	2.40	1.32
1688.1	661.04	2546.	1368.	712.	836.	8.26	4.41	2.34	1.26
1588.1	682.60	2640.	1413.	733.	831.	8.23	4.36	2.29	1.22
1488.1	704.20	2738.	1460.	753.	829.	8.21	4.32	2.25	1.18
1388.1	725.86	2838.	1509.	774.	828.	8.19	4.29	2.21	1.14
1288.1	747.46	2941.	1559.	796.	828.	8.19	4.26	2.17	1.11
1188.1	768.93	3047.	1611.	818.	831.	8.20	4.24	2.14	1.08
1088.1	790.22	3159.	1664.	841.	836.	8.23	4.23	2.12	1.06
988.1	811.27	3275.	1721.	865.	844.	8.26	4.23	2.11	1.04
888.1	832.05	3398.	1781.	890.	854.	8.32	4.24	2.10	1.03
788.1	852.50	3530.	1846.	917.	868.	8.40	4.26	2.09	1.02
688.1	872.59	3674.	1919.	947.	888.	8.51	4.30	2.10	1.02
588.1	892.31	3835.	2002.	981.	909.	8.66	4.36	2.12	1.02
488.1	911.64	4021.	2101.	1022.	933.	8.86	4.45	2.14	1.02
388.1	930.53	4249.	2230.	1075.	963.	9.15	4.59	2.19	1.04
288.1	948.97	4549.	2422.	1157.	1009.	9.63	4.83	2.28	1.06
188.1	966.96	4982.	2776.	1323.	1104.	10.53	5.38	2.51	1.14
88.1	984.52	5438.	3627.	1880.	1503.	12.64	7.12	3.44	1.53
14.7	996.78	5651.	4049.	2095.	1409.	13.25	7.58	3.52	1.41

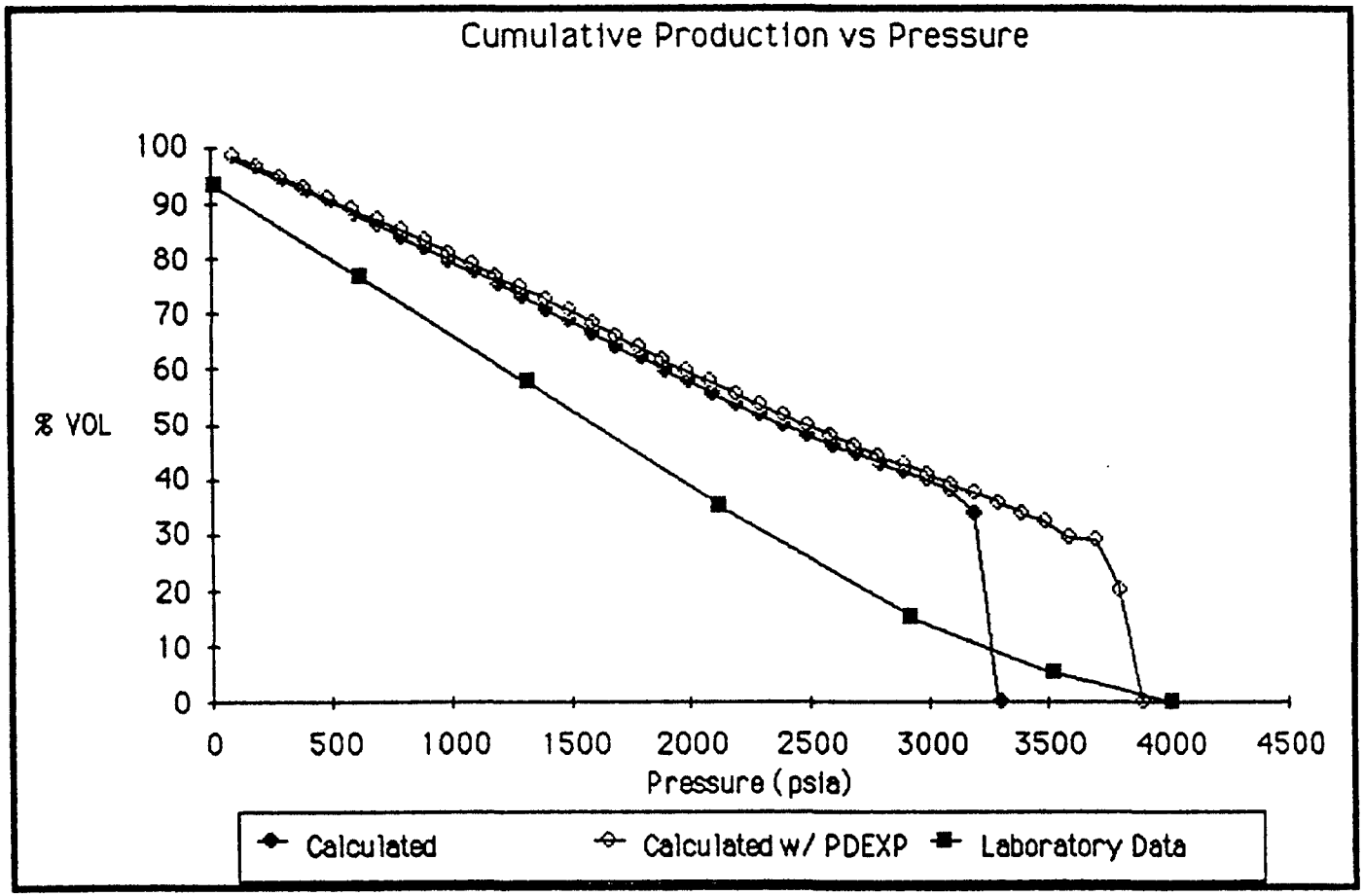

Figure 4.25 Gas Condensate Sample 1, Cumulative Production

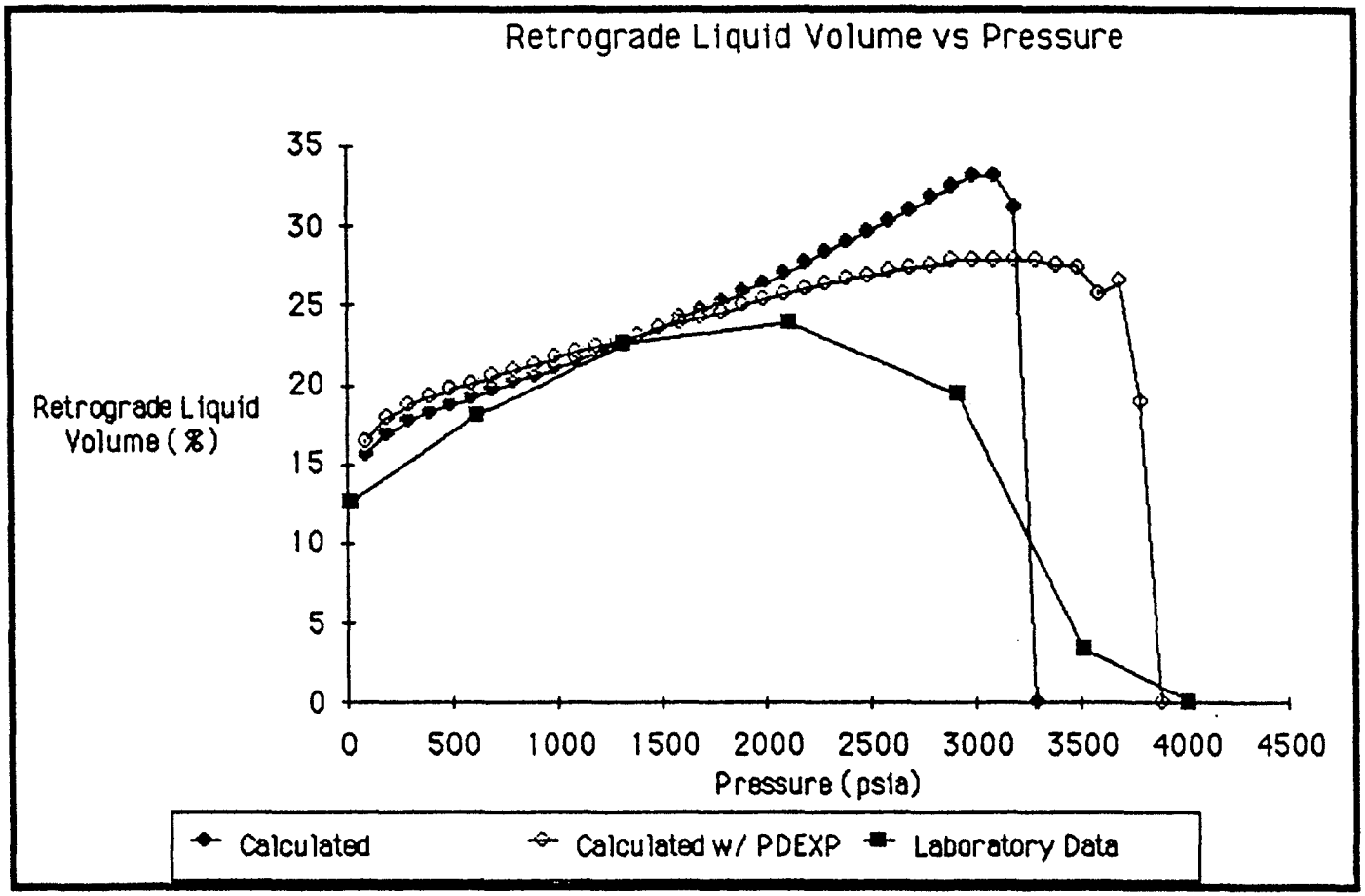

Figure 4.26 Gas Condensate Sample 1, Retrograde Liquid Volume

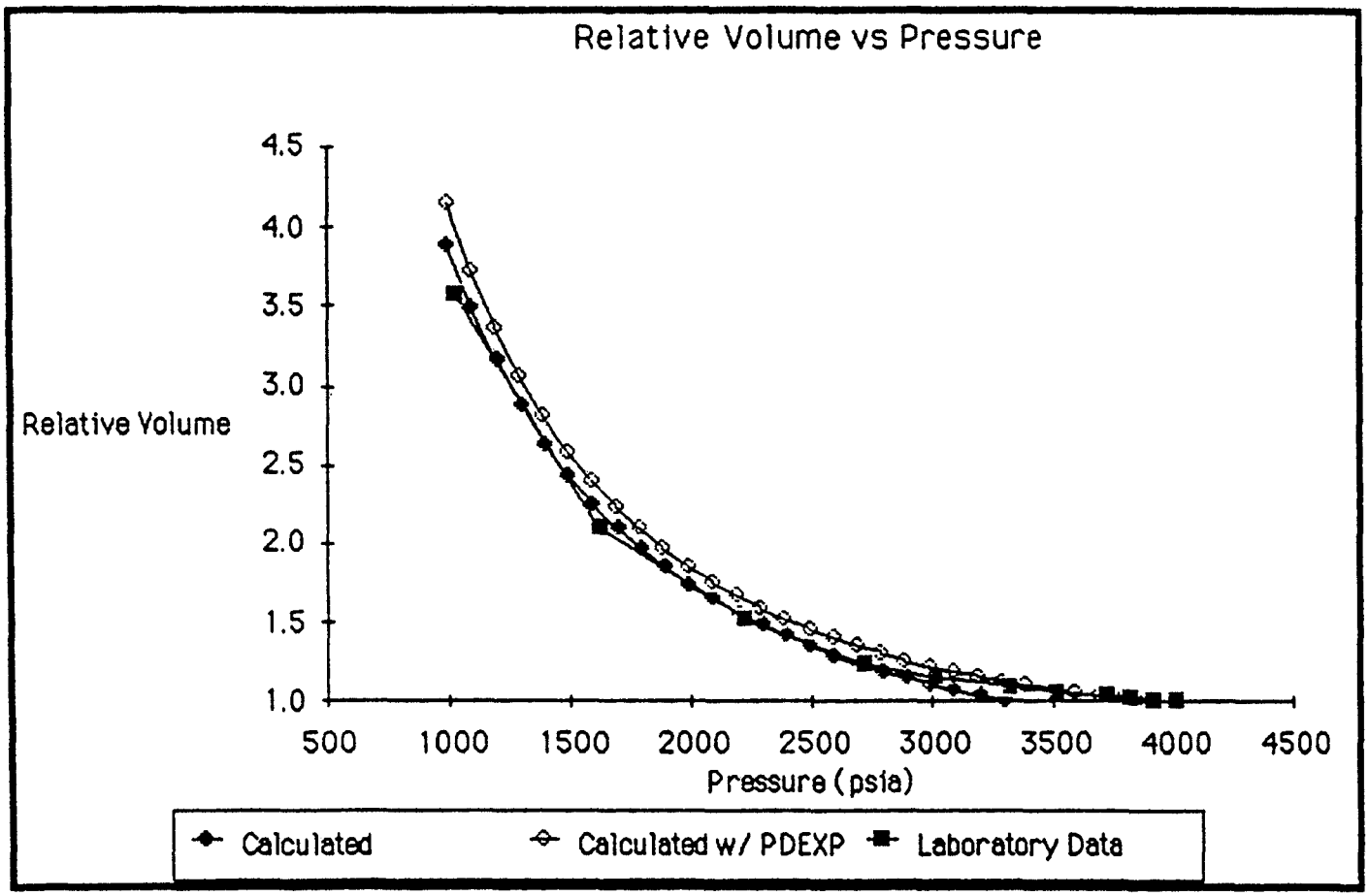

Figure 4.27 Gas Condensate Sample 1, Relative Volume

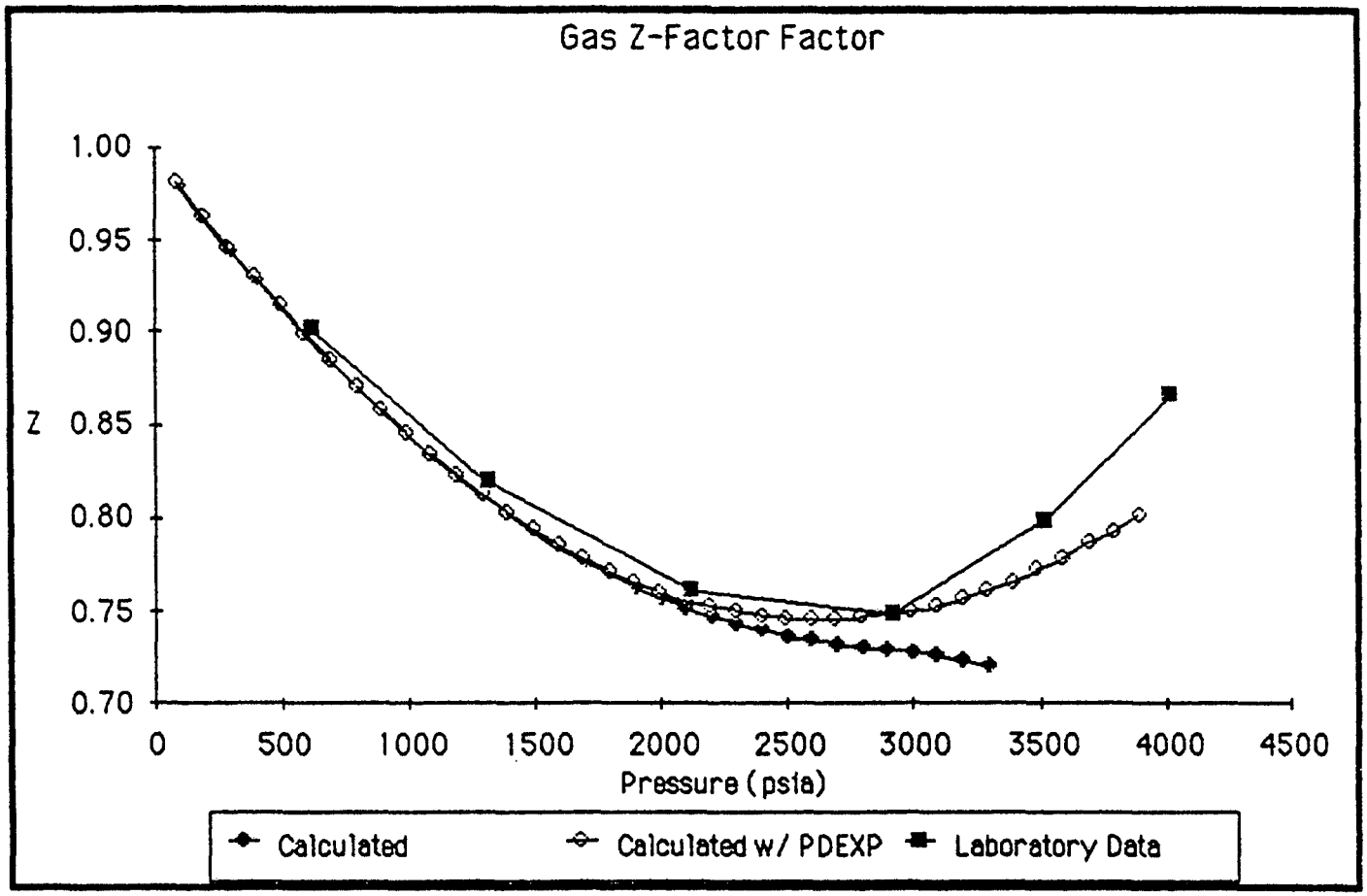

Figure 4.28 Gas Condensate Sample 1, Gas Z-Factor

Table 4.15 Summary of Results for Gas Condensate Sample 1

	Constant Volume Depletion Study	
PVT Property	AMPE (%)	AAPE (%)
Cumulative Production	185	84.8
with PBEXP	192	89.3
Retrograde Liquid Volume	91	25.15
with PBEXP	64	25.75
Relative Volume	3.5	1.67
with PBEXP	8.3	6.83
Gas Z-Factor	6.6	3.2
with PBEXP	1.7	0.78
Average Error		28.71
with PBEXP		30.67

Table 4.16 Gas Condensate Sample 2 Output

```
          ########################################
          # RETROGRADE CONDENSATE PVT ANALYSIS #
          ########################################

METHOD/CORRELATION USED          PURPOSE
-----------------------          -------


ESTIMATED PROPERTIES OF HEAVY-PLUS ARE :

      NORMAL BOILING POINT TEMP. =  369.94  DEG.F
      CRITICAL TEMPERATURE =    695.77  DEG.F
      CRITICAL PRESSURE    =    333.25  PSIA
      ACENTRIC FACTOR      =    .4863
ACCD. SUCCESSIVE SUBSTITUTION    ITERATIVE ESTIMATION OF K-VALUES
GRABOWSKI-DAUBERT                N2-H/C,CO2-H/C AND H2S-H/C BINARY
                                 INTERACTION PARAMETERS ESTIMATION

INITIAL RESERVOIR CONDITIONS AND COMPOSITION (GIVEN)
----------------------------------------------------
RESERVOIR TEMPERATURE =    270.0   DEG.F
RESERVOIR PRESSURE    =    5174.70  PSIA
FIRST DEW POINT PRESSURE (EXPT) = NOT GIVEN


COMPONENT                MOLE FRACTION
---------                -------------
N2                          .00110
H2S                         .03990
CO2                         .06020
METHANE                     .76110
ETHANE                      .05390
PROPANE                     .01970
I-BUTANE                    .00510
N-BUTANE                    .00930
I-PENTANE                   .00370
N-PENTANE                   .00500
HEXANES                     .00590
HEAVY+                      .03510

HEAVY-PLUS:MOLECULAR WEIGHT =    157.
           SPECIFIC GRAVITY =     .78700


EST.DEW POINT PRESSURE (NEMETH-KENNEDY CORRELATION)  =     5227.76  PSIA

CALCULATED FIRST DEW POINT PRESSURE =     3449.99  PSIA

CALCULATED SECOND DEW POINT PRESSURE =      89.99  PSIA
```

Table 4.16 Continued

\# CONSTANT VOLUME DEPLETION STUDY #

PRESSURE (PSIA)	TEMP (DEG.F)	CUMULATIVE RETROGRADE CONDENSATION (%)	RELATIVE VOLUME	CUMULATIVE GAS PRODUCED (% VOL)	GAS FVF (CU.FT/SCF)	GAS Z FACTOR	GAS GRAVITY (AIR=1)	GAS VISCOSITY (CP)	LIQUID DENSITY (GM/CC)
3450.0	270.0	.00	1.000	.00	.0053	.8825	.905	.0247	.5360
3350.0	270.0	.83	1.029	3.59	.0054	.8814	.893	.0239	.5432
3250.0	270.0	1.52	1.059	7.03	.0056	.8806	.882	.0233	.5499
3150.0	270.0	2.08	1.092	10.35	.0058	.8800	.873	.0226	.5562
3050.0	270.0	2.55	1.128	13.58	.0059	.8797	.864	.0221	.5624
2950.0	270.0	2.95	1.166	16.73	.0061	.8796	.855	.0215	.5683
2850.0	270.0	3.27	1.207	19.83	.0064	.8797	.848	.0210	.5744
2750.0	270.0	3.54	1.251	22.89	.0066	.8800	.841	.0205	.5799
2650.0	270.0	3.77	1.299	25.92	.0068	.8806	.834	.0201	.5853
2550.0	270.0	3.95	1.351	28.92	.0071	.8814	.828	.0197	.5906
2450.0	270.0	4.10	1.408	31.90	.0074	.8825	.823	.0193	.5957
2350.0	270.0	4.23	1.470	34.86	.0077	.8838	.818	.0189	.6008
2250.0	270.0	4.32	1.538	37.80	.0081	.8853	.813	.0186	.6057
2150.0	270.0	4.40	1.613	40.73	.0085	.8871	.809	.0182	.6106
2050.0	270.0	4.46	1.696	43.65	.0089	.8892	.805	.0179	.6153
1950.0	270.0	4.50	1.787	46.57	.0094	.8915	.802	.0176	.6200
1850.0	270.0	4.52	1.889	49.47	.0099	.8941	.799	.0173	.6246
1750.0	270.0	4.53	2.004	52.36	.0106	.8970	.796	.0170	.6292
1650.0	270.0	4.54	2.133	55.24	.0112	.9001	.794	.0168	.6336
1550.0	270.0	4.53	2.279	58.10	.0120	.9035	.792	.0165	.6381
1450.0	270.0	4.51	2.446	60.96	.0129	.9072	.790	.0163	.6425
1350.0	270.0	4.49	2.639	63.80	.0139	.9112	.789	.0161	.6467
1250.0	270.0	4.46	2.863	66.63	.0151	.9154	.789	.0158	.6510
1150.0	270.0	4.42	3.127	69.44	.0165	.9200	.789	.0156	.6552
1050.0	270.0	4.38	3.443	72.23	.0181	.9248	.789	.0154	.6593
950.0	270.0	4.33	3.827	75.00	.0202	.9300	.790	.0153	.6635
850.0	270.0	4.28	4.302	77.75	.0227	.9354	.793	.0151	.6676
750.0	270.0	4.22	4.906	80.48	.0258	.9412	.795	.0149	.6716
650.0	270.0	4.17	5.699	83.18	.0300	.9475	.798	.0147	.6757
550.0	270.0	4.11	6.782	85.86	.0357	.9542	.802	.0146	.6799
450.0	270.0	4.06	8.351	88.51	.0440	.9613	.807	.0144	.6840
350.0	270.0	4.00	10.822	91.13	.0570	.9688	.814	.0143	.6883
250.0	270.0	3.94	15.276	93.71	.0804	.9769	.824	.0142	.6929
150.0	270.0	3.86	25.685	96.26	.1353	.9854	.844	.0140	.6981
14.7	60.0	3.50	188.632	99.49	.9933	.9958	.810	.0100	.7761

Table 4.16 Continued

CALCULATED RECOVERY DURING DEPLETION
(PER MMSCF OF ORIGINAL FLUID)

PRESSURE (PSIA)	GAS PHASE (MSCF)	PLANT PRODUCTS IN GAS PHASE, GALLONS				GPM			
		ETHANE	PROPANE	BUTANES	PENTANES+	ETHANE+	PROPANE+	BUTANE+	PENTANE+
3450.0	.00	0.	0.	0.	0.	5.20	3.76	3.22	2.76
3350.0	35.91	52.	19.	16.	94.	5.04	3.61	3.07	2.61
3250.0	70.29	101.	38.	32.	174.	4.90	3.46	2.92	2.47
3150.0	103.48	149.	56.	47.	242.	4.77	3.33	2.79	2.34
3050.0	135.76	196.	73.	61.	302.	4.65	3.21	2.67	2.22
2950.0	167.34	242.	90.	75.	354.	4.54	3.10	2.56	2.11
2850.0	198.34	287.	106.	89.	399.	4.44	3.00	2.46	2.01
2750.0	228.93	332.	123.	102.	439.	4.35	2.90	2.36	1.92
2650.0	259.19	376.	139.	116.	474.	4.27	2.81	2.28	1.83
2550.0	289.18	421.	156.	129.	506.	4.19	2.73	2.19	1.75
2450.0	318.96	465.	172.	142.	534.	4.12	2.66	2.12	1.67
2350.0	348.56	510.	188.	155.	559.	4.05	2.59	2.05	1.60
2250.0	378.01	555.	204.	168.	582.	3.99	2.52	1.98	1.54
2150.0	407.34	600.	221.	181.	602.	3.94	2.46	1.92	1.48
2050.0	436.55	645.	237.	194.	621.	3.89	2.41	1.87	1.42
1950.0	465.66	691.	254.	208.	639.	3.85	2.36	1.82	1.37
1850.0	494.66	737.	271.	221.	655.	3.81	2.32	1.77	1.32
1750.0	523.56	784.	288.	235.	671.	3.78	2.28	1.73	1.28
1650.0	552.36	831.	306.	248.	687.	3.75	2.25	1.69	1.24
1550.0	581.03	880.	324.	262.	703.	3.73	2.22	1.66	1.21
1450.0	609.59	929.	342.	277.	719.	3.72	2.19	1.63	1.18
1350.0	638.01	979.	361.	291.	735.	3.71	2.17	1.61	1.15
1250.0	666.28	1031.	380.	307.	754.	3.71	2.16	1.59	1.13
1150.0	694.38	1084.	400.	322.	774.	3.72	2.15	1.58	1.11
1050.0	722.29	1139.	421.	339.	797.	3.73	2.16	1.57	1.10
950.0	750.01	1195.	443.	356.	823.	3.76	2.16	1.57	1.10
850.0	777.49	1255.	467.	375.	857.	3.80	2.19	1.58	1.10
750.0	804.78	1318.	493.	395.	893.	3.85	2.21	1.60	1.11
650.0	831.83	1385.	521.	417.	930.	3.91	2.24	1.62	1.12
550.0	858.62	1458.	552.	442.	970.	3.99	2.29	1.64	1.13
450.0	885.12	1540.	589.	472.	1016.	4.09	2.35	1.68	1.15
350.0	911.29	1633.	635.	509.	1072.	4.22	2.43	1.74	1.18
250.0	937.12	1746.	697.	562.	1149.	4.43	2.57	1.83	1.23
150.0	962.57	1893.	796.	655.	1288.	4.81	2.85	2.02	1.34
14.7	994.88	2121.	928.	740.	706.	4.52	2.39	1.45	.71

Table 4.17 Gas Condensate Sample 2 Output with Experimental Dew Point Given

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          ########################################
          # RETROGRADE CONDENSATE PVT ANALYSIS #
          ########################################

METHOD/CORRELATION USED          PURPOSE
-----------------------          -------

ESTIMATED PROPERTIES OF HEAVY-PLUS ARE :

      NORMAL BOILING POINT TEMP. =  369.94  DEG.F
      CRITICAL TEMPERATURE =    695.77  DEG.F
      CRITICAL PRESSURE    =    333.25  PSIA
      ACENTRIC FACTOR      =    .4863
ACCD. SUCCESSIVE SUBSTITUTION    ITERATIVE ESTIMATION OF K-VALUES
GRABOWSKI-DAUBERT                N2-H/C,CO2-H/C AND H2S-H/C BINARY
                                 INTERACTION PARAMETERS ESTIMATION

INITIAL RESERVOIR CONDITIONS AND COMPOSITION (GIVEN)
----------------------------------------------------
RESERVOIR TEMPERATURE =    270.0   DEG.F
RESERVOIR PRESSURE    =    5174.70  PSIA
FIRST DEW POINT PRESSURE (EXPT) =    5174.70  PSIA


COMPONENT                MOLE FRACTION
---------                -------------
N2                          .00110
H2S                         .03990
CO2                         .06020
METHANE                     .76110
ETHANE                      .05390
PROPANE                     .01970
I-BUTANE                    .00510
N-BUTANE                    .00930
I-PENTANE                   .00370
N-PENTANE                   .00500
HEXANES                     .00590
HEAVY+                      .03510

HEAVY-PLUS:MOLECULAR WEIGHT =    157.
           SPECIFIC GRAVITY =     .78700


EST.DEW POINT PRESSURE (NEMETH-KENNEDY CORRELATION)  =     5227.76  PSIA

CALCULATED FIRST DEW POINT PRESSURE =     4889.99  PSIA

CALCULATED SECOND DEW POINT PRESSURE =      89.99  PSIA
```

Table 4.17 Continued

CONSTANT VOLUME DEPLETION STUDY

PRESSURE (PSIA)	TEMP (DEG.F)	CUMULATIVE RETROGRADE CONDENSATION (%)	RELATIVE VOLUME	CUMULATIVE GAS PRODUCED (% VOL)	GAS FVF (CU.FT/SCF)	GAS Z FACTOR	GAS GRAVITY (AIR=1)	GAS VISCOSITY (CP)	LIQUID DENSITY (GM/CC)
4890.0	270.0	.00	1.000	.00	.0041	.9753	.905	.0315	.0000
4790.0	270.0	.52	1.014	1.94	.0042	.9691	.899	.0308	.5802
4690.0	270.0	1.02	1.030	3.88	.0042	.9632	.893	.0301	.5832
4590.0	270.0	1.48	1.046	5.81	.0043	.9575	.887	.0294	.5856
4490.0	270.0	1.91	1.063	7.73	.0044	.9520	.881	.0287	.5881
4390.0	270.0	2.30	1.081	9.65	.0044	.9468	.875	.0281	.5905
4290.0	270.0	2.66	1.101	11.57	.0045	.9418	.870	.0275	.5929
4190.0	270.0	3.00	1.121	13.48	.0046	.9370	.864	.0269	.5953
4090.0	270.0	3.30	1.143	15.41	.0047	.9325	.859	.0263	.5976
3990.0	270.0	3.58	1.166	17.33	.0048	.9282	.854	.0258	.6001
3890.0	270.0	3.84	1.191	19.27	.0049	.9241	.850	.0252	.6029
3790.0	270.0	4.07	1.218	21.21	.0050	.9203	.845	.0247	.6051
3690.0	270.0	4.29	1.246	23.17	.0051	.9168	.840	.0242	.6074
3590.0	270.0	4.49	1.276	25.13	.0052	.9135	.836	.0237	.6097
3490.0	270.0	4.67	1.308	27.11	.0054	.9104	.832	.0232	.6121
3390.0	270.0	4.83	1.342	29.11	.0055	.9076	.828	.0228	.6144
3290.0	270.0	4.98	1.379	31.11	.0057	.9051	.824	.0223	.6167
3190.0	270.0	5.11	1.419	33.13	.0058	.9029	.820	.0219	.6190
3090.0	270.0	5.23	1.462	35.17	.0060	.9009	.817	.0214	.6213
2990.0	270.0	5.34	1.508	37.22	.0062	.8992	.813	.0210	.6237
2890.0	270.0	5.43	1.558	39.29	.0064	.8978	.810	.0206	.6260
2790.0	270.0	5.51	1.611	41.36	.0066	.8967	.807	.0203	.6284
2690.0	270.0	5.59	1.670	43.46	.0069	.8959	.804	.0199	.6307
2590.0	270.0	5.64	1.733	45.56	.0071	.8954	.801	.0195	.6331
2490.0	270.0	5.69	1.802	47.68	.0074	.8951	.798	.0192	.6355
2390.0	270.0	5.73	1.878	49.81	.0077	.8952	.796	.0189	.6379
2290.0	270.0	5.76	1.961	51.94	.0081	.8956	.794	.0185	.6402
2190.0	270.0	5.79	2.052	54.09	.0084	.8963	.792	.0182	.6426
2090.0	270.0	5.80	2.153	56.24	.0088	.8974	.790	.0179	.6451
1990.0	270.0	5.81	2.264	58.40	.0093	.8987	.788	.0176	.6475
1890.0	270.0	5.81	2.389	60.57	.0098	.9004	.787	.0174	.6499
1790.0	270.0	5.80	2.528	62.73	.0104	.9024	.786	.0171	.6524
1690.0	270.0	5.79	2.684	64.90	.0110	.9047	.785	.0168	.6548
1590.0	270.0	5.77	2.861	67.07	.0117	.9074	.784	.0166	.6573
1490.0	270.0	5.75	3.063	69.23	.0126	.9104	.783	.0164	.6598
1390.0	270.0	5.72	3.296	71.40	.0135	.9137	.783	.0161	.6624
1290.0	270.0	5.69	3.566	73.55	.0146	.9174	.784	.0159	.6649
1190.0	270.0	5.65	3.882	75.70	.0159	.9214	.784	.0157	.6674
1090.0	270.0	5.61	4.258	77.83	.0175	.9257	.785	.0155	.6700
990.0	270.0	5.56	4.712	79.96	.0193	.9304	.787	.0153	.6726
890.0	270.0	5.51	5.270	82.07	.0216	.9354	.789	.0152	.6753
790.0	270.0	5.47	5.971	84.17	.0245	.9409	.792	.0150	.6779
690.0	270.0	5.41	6.880	86.25	.0282	.9467	.795	.0148	.6807
590.0	270.0	5.36	8.099	88.31	.0333	.9530	.799	.0147	.6835
490.0	270.0	5.31	9.820	90.36	.0403	.9597	.804	.0145	.6864
390.0	270.0	5.25	12.430	92.38	.0510	.9668	.810	.0144	.6895
290.0	270.0	5.18	16.847	94.37	.0692	.9744	.820	.0142	.6930
190.0	270.0	5.10	25.927	96.34	.1065	.9825	.836	.0140	.6971
14.7	60.0	4.57	241.949	99.61	.9934	.9958	.820	.0099	.7768

Table 4.17 Continued

CALCULATED RECOVERY DURING DEPLETION
(PER MMSCF OF ORIGINAL FLUID)

PRESSURE (PSIA)	GAS PHASE (MSCF)	PLANT PRODUCTS IN GAS PHASE, GALLONS				GPM			
		ETHANE	PROPANE	BUTANES	PENTANES+	ETHANE+	PROPANE+	BUTANE+	PENTANE+
4890.0	.00	0.	0.	0.	0.	5.21	3.77	3.23	2.77
4790.0	19.37	28.	10.	9.	52.	5.13	3.69	3.15	2.69
4690.0	38.79	56.	21.	18.	101.	5.04	3.61	3.07	2.61
4590.0	58.09	84.	31.	26.	147.	4.96	3.53	2.99	2.53
4490.0	77.32	111.	42.	35.	190.	4.89	3.45	2.91	2.45
4390.0	96.50	139.	52.	44.	230.	4.81	3.37	2.83	2.38
4290.0	115.66	166.	62.	52.	267.	4.74	3.30	2.76	2.31
4190.0	134.85	194.	72.	61.	302.	4.67	3.23	2.69	2.24
4090.0	154.07	222.	83.	69.	335.	4.60	3.16	2.62	2.17
3990.0	173.34	250.	93.	78.	365.	4.53	3.09	2.55	2.11
3890.0	192.65	278.	103.	86.	393.	4.47	3.03	2.49	2.04
3790.0	212.10	306.	114.	95.	420.	4.41	2.96	2.43	1.98
3690.0	231.66	335.	124.	103.	445.	4.35	2.90	2.37	1.92
3590.0	251.32	364.	135.	112.	468.	4.29	2.84	2.31	1.86
3490.0	271.13	393.	145.	121.	489.	4.23	2.79	2.25	1.80
3390.0	291.06	422.	156.	129.	509.	4.18	2.73	2.19	1.75
3290.0	311.13	452.	167.	138.	528.	4.13	2.68	2.14	1.70
3190.0	331.35	482.	178.	147.	545.	4.08	2.62	2.09	1.65
3090.0	351.71	512.	189.	156.	561.	4.03	2.57	2.04	1.60
2990.0	372.21	543.	200.	165.	576.	3.99	2.53	1.99	1.55
2890.0	392.85	575.	211.	173.	590.	3.94	2.48	1.94	1.50
2790.0	413.64	606.	222.	182.	603.	3.90	2.44	1.90	1.46
2690.0	434.61	639.	234.	192.	614.	3.86	2.39	1.85	1.41
2590.0	455.64	671.	245.	201.	626.	3.83	2.35	1.81	1.37
2490.0	476.79	704.	257.	210.	636.	3.79	2.31	1.78	1.33
2390.0	498.06	738.	269.	219.	647.	3.76	2.28	1.74	1.30
2290.0	519.43	772.	281.	229.	656.	3.73	2.24	1.70	1.26
2190.0	540.89	807.	294.	238.	665.	3.70	2.21	1.67	1.23
2090.0	562.42	842.	306.	248.	674.	3.68	2.18	1.64	1.20
1990.0	584.02	878.	319.	258.	683.	3.66	2.16	1.61	1.17
1890.0	605.66	915.	332.	267.	691.	3.64	2.13	1.58	1.14
1790.0	627.33	953.	345.	277.	700.	3.63	2.11	1.56	1.12
1690.0	649.01	991.	358.	288.	709.	3.62	2.09	1.54	1.09
1590.0	670.69	1030.	372.	298.	719.	3.61	2.07	1.52	1.07
1490.0	692.34	1071.	386.	309.	729.	3.60	2.06	1.50	1.05
1390.0	713.95	1113.	401.	320.	741.	3.61	2.05	1.49	1.04
1290.0	735.50	1156.	416.	331.	754.	3.61	2.04	1.47	1.02
1190.0	756.97	1200.	432.	342.	769.	3.62	2.04	1.47	1.02
1090.0	778.34	1247.	448.	355.	786.	3.64	2.04	1.47	1.01
990.0	799.58	1295.	466.	367.	809.	3.67	2.05	1.47	1.01
890.0	820.70	1347.	484.	381.	833.	3.71	2.07	1.48	1.01
790.0	841.69	1403.	505.	396.	857.	3.75	2.09	1.49	1.02
690.0	862.51	1463.	527.	412.	883.	3.81	2.11	1.50	1.02
590.0	883.15	1530.	552.	430.	911.	3.88	2.14	1.52	1.03
490.0	903.57	1605.	582.	452.	943.	3.96	2.19	1.54	1.04
390.0	923.77	1695.	618.	479.	981.	4.08	2.25	1.58	1.06
290.0	943.72	1807.	668.	517.	1032.	4.26	2.35	1.64	1.09
190.0	963.40	1961.	748.	581.	1120.	4.58	2.54	1.77	1.16
14.7	996.06	2314.	936.	692.	621.	4.58	2.26	1.32	.62

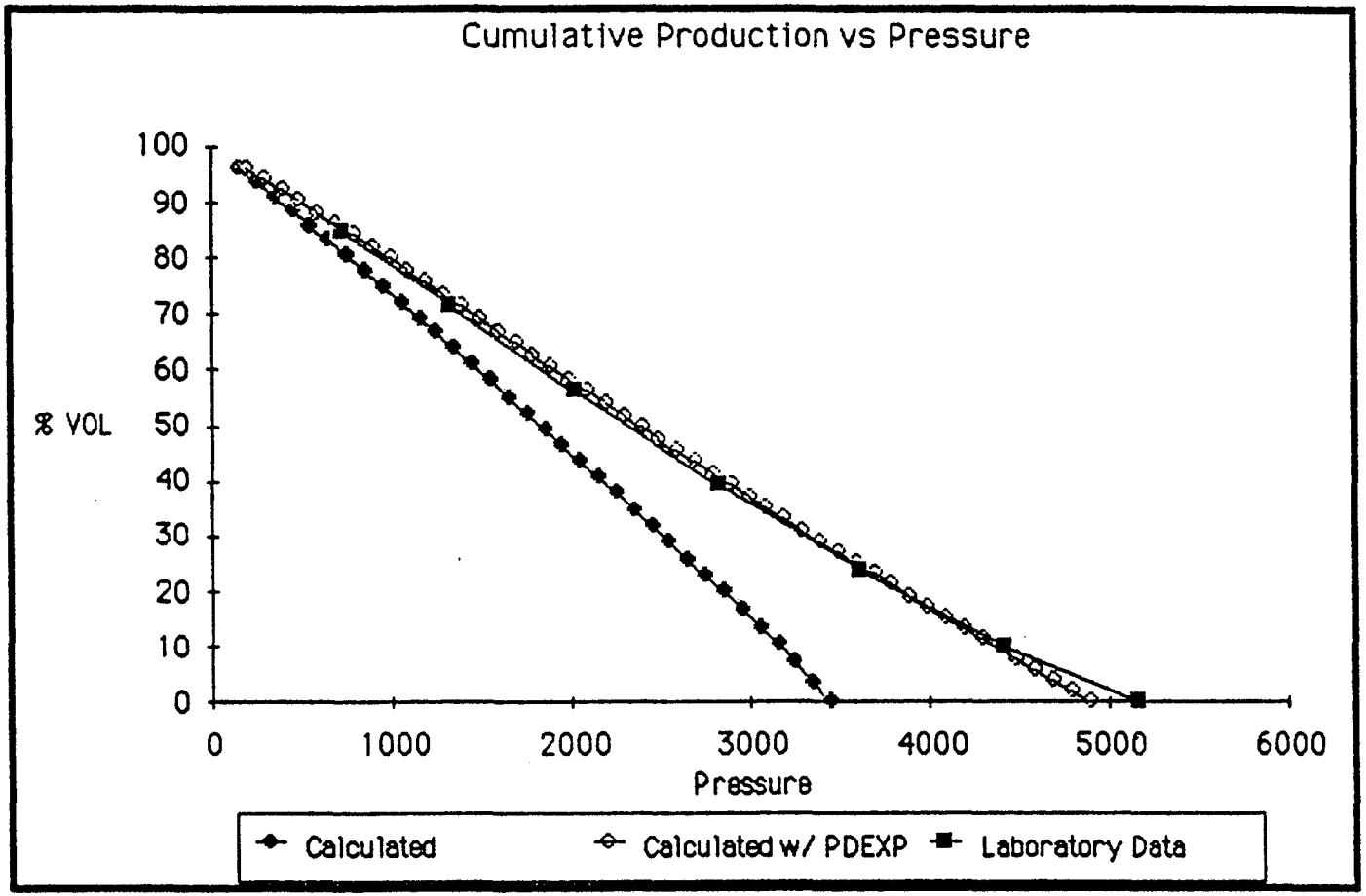

Figure 4.29 Gas Condensate Sample 2, Cumulative Production

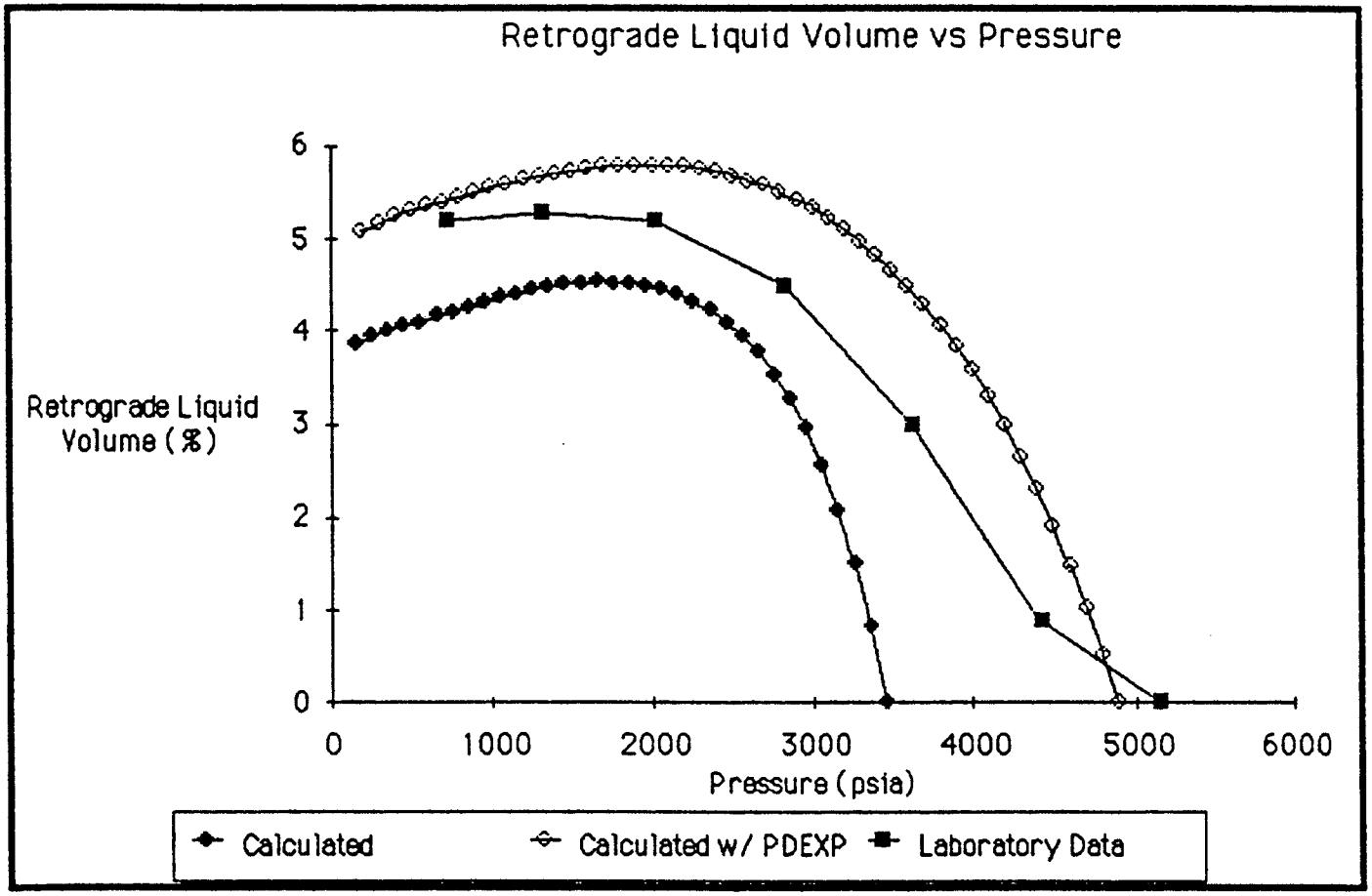

Figure 4.30 Gas Condensate Sample 2, Retrograde Liquid Volume

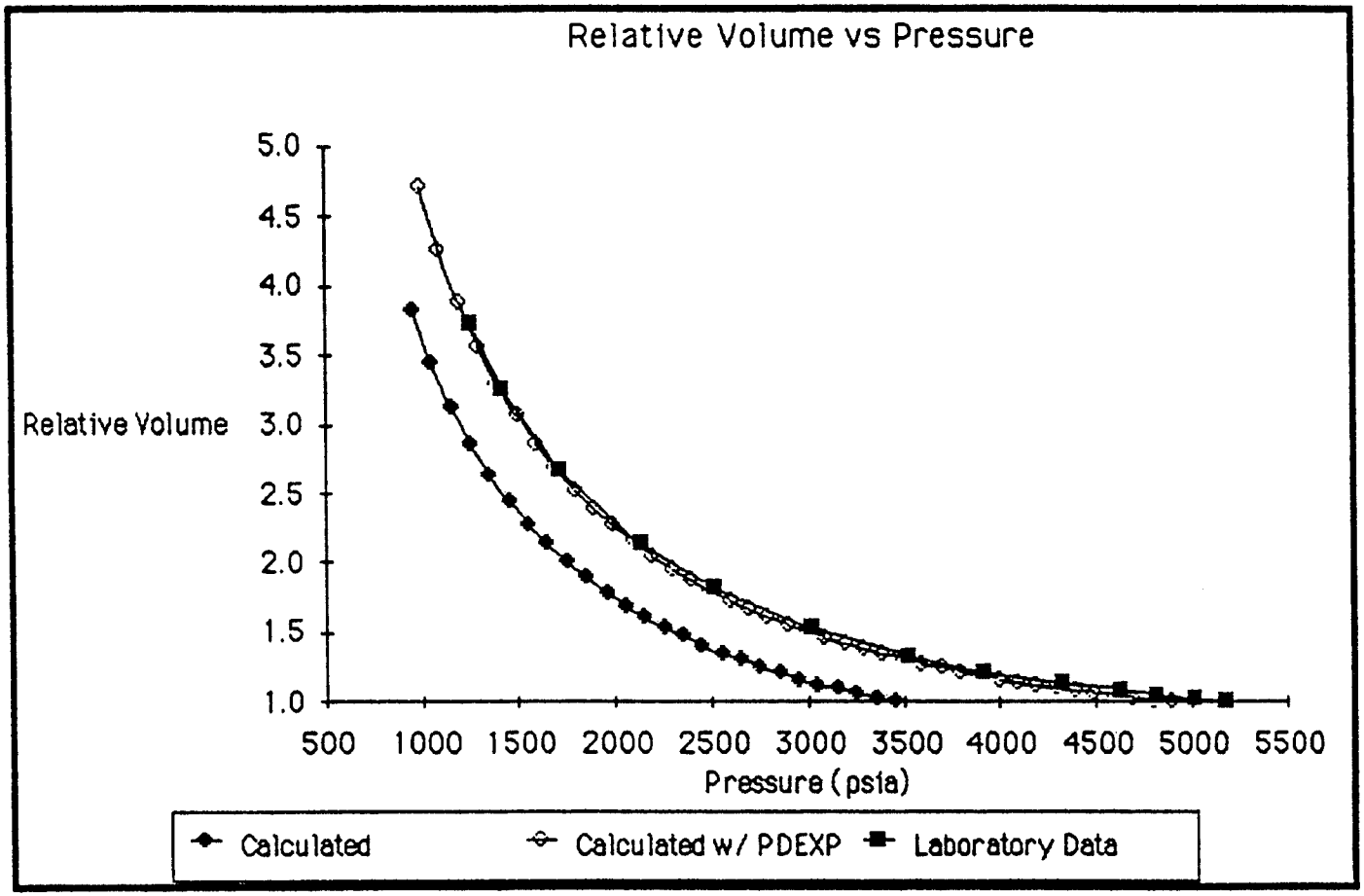

Figure 4.31 Gas Condensate Sample 2, Relative Volume

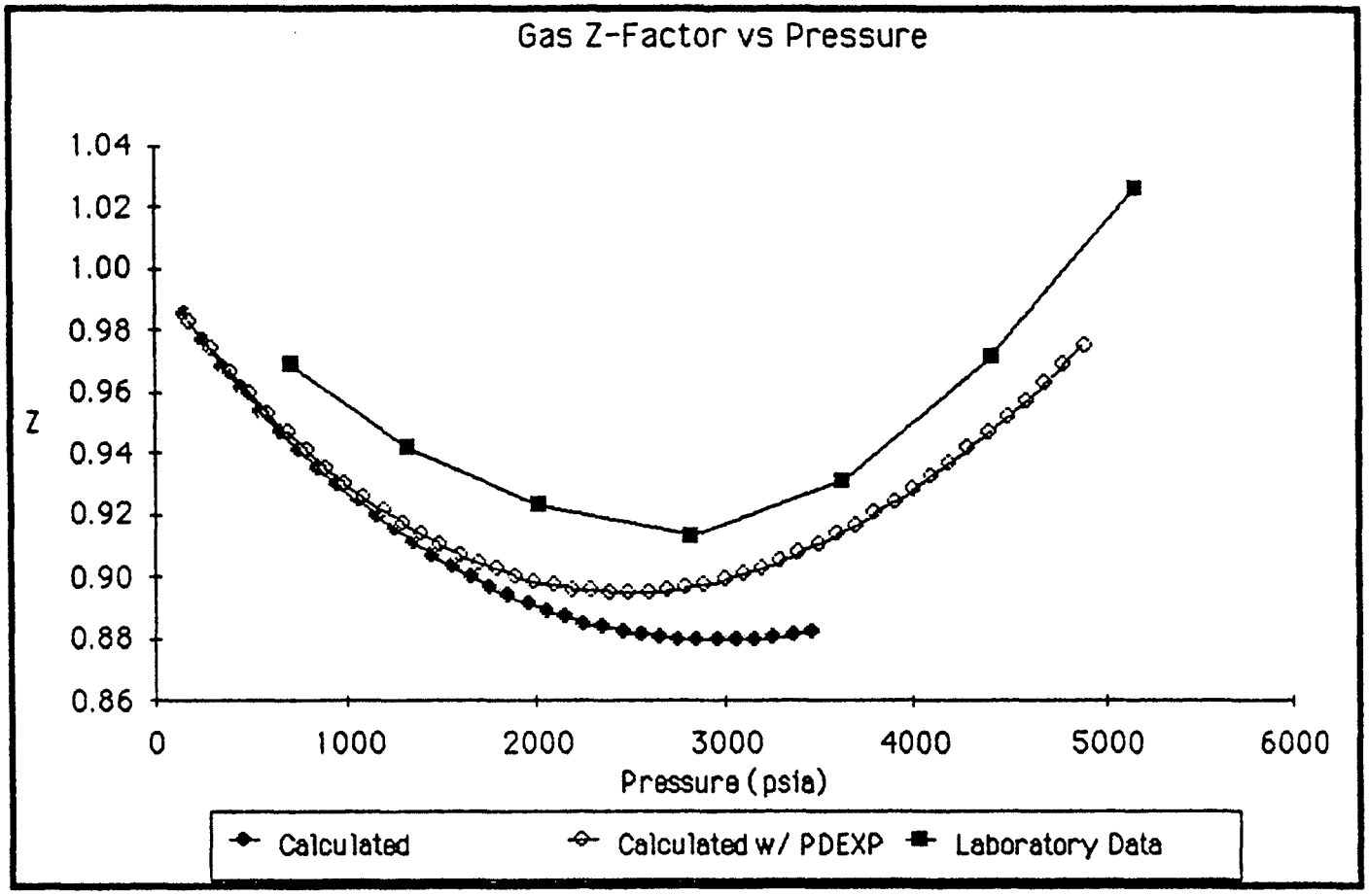

Figure 4.32 Gas Condensate Sample 2, Gas Z-Factor

Table 4.18 Summary of Results for Gas Condensate Sample 2

	Constant Volume Depletion Study	
PVT Property	AMPE (%)	AAPE (%)
Cumulative Production	55.6	27.47
with PBEXP	3.51	2.09
Retrograde Liquid Volume	33.73	21.18
with PBEXP	27.71	15.33
Relative Volume	25.73	21.75
with PBEXP	6.25	3.46
Gas Z-Factor	4.03	3.51
with PBEXP	2.72	2.39
Average Error		18.48
with PBEXP		5.82

CHAPTER 5

RUNNING THE PROGRAMS

5.1 Introduction

The program has been designed to be user friendly. While this makes it easy for the user to input the data, it is essential to understand the input conventions before attempting to use the program. The input subroutine allows for editing of input data for corrections or for changing parameters and options of previously saved input data. The input files created using the input subroutine is the same for all three programs. This is convenient if the user inappropriately judges the sample type and runs the wrong program.

5.2 Preparation of Data

The user should collect and organize all necessary data prior to running the program. The data which are needed are given below in the order in which they will be requested by the program. Those noted with an asterisk (*) are optional.

(1) Type of Sample

  (a) Recombination

  (b) Well-stream

(2) Compositional Data

  (a) Recombination requires overall mole fractions

(b) Well-stream requires both liquid and gas mole fractions

(NOTE: Mole fractions will be used, not mole percent)

(3) Molecular weight of the liquid heavy-plus

(4) Specific gravity of the liquid heavy-plus

(5)* Molecular weight of the vapor phase heavy-plus

(6)* Specific gravity of the vapor phase heavy-plus

(NOTE: Although both 5 and 6 are optional, they cannot be used exclusively of one another)

(7) System gas-oil ratio (not required for well-stream)

(8) System pressure

(9) System temperature

(10)* Experimental bubble point or dew point pressure

5.3 PC-DOS File Naming Convention

Filenames must conform to the following simple rules:

1. The name must be from one to eight characters long, with no spaces

2. The characters acceptable in a filename are:

   a. Letters of the alphabet

   b. Numbers 0 through 9

   c. Special characters $ # & @ ! % ( ) - { } ' _'

3. Filenames can be followed by an optional extension separated from the file name by a period (.). The extension may have up to three characters from the set acceptable for filenames.

In order to locate or place a file on the intended disk it is necessary to include a drive specifier. A drive specifier consists of a letter followed by a colon. The letter represents the disk drive onto which the file will be read or written. The drive specifier is typed directly in front of the filename with no spaces in between. On most systems, the default drive is labeled drive A: and aditional drives are labled B:, C:, and D:. For example, if the program disk is in drive A: and you want to save an input file called WELL2 on the second disk drive and put an extension "VO" on it to signify it is a volatile oil sample the complete input file response would be as follows: B:WELL2.VO. Consult your user manual for further details on drive specifiers on your particular system.

5.4 Printer Setup

If a printed copy of the output is desired at runtime, the printer must be set in the 132 column mode. This must be done with a DOS command before starting the program. For a standard equipped

IBM-PC with an IBM personal computer graphics printer, this can be accomplished with the following command:

MODE LPT1:132,8,P

If you have another type of PC-DOS computer or different type of printer you should consult the user manual for the appropriate procedure.

5.5 Inputting Data

The first prompt asks whether the user will input data or retrieve a data input file. Unless you have previously saved data from a previous run, you will input data for calculations. If you retrieve a data file, the program will proceed directly to the data review editor.

5.5.1 Type of Sample

The type of sample, either recombination or well-stream, is selected by inputting the number '1' for recombination or the number '2' for well-stream. This selection is permanent for the present input data and is retained in any input file created from the input data.

5.5.2 Inputting Mole Fractions

The program will prompt you for mole fractions of the following sixteen components in the order they are presented:

(1) N2 (nitrogen)

(2) H2S (hydrogen sulfide)

(3) CO2 (carbon dioxide)

(4) METHANE

(5) ETHANE

(6) PROPENE

(7) I-BUTANE

(8) N-BUTANE

(9) I-PENTANE

(10) N-PENTANE

(11) HEXANES

(12) HEPTANES

(13) OCTANES

(14) NONANE

(15) DECANES

(16) HEAVY+ (heavy ends lump)

For a recombination fluid sample, the liquid mole fraction followed by a comma and then the vapor mole fraction are entered. Well stream samples require only the overall mole fraction. If the prompted component is not a part of the sample or the component is above the heavy-plus, zeros should be entered (NOTE: Recombination requires two zeros with a comma in between, i.e. "0,0").

Generally, the hydrocarbon components should be specified through at least pentane. This would have a heavy-ends cut of hexane-plus. It is more common today to have a hydrocarbon analysis specified through hexane and have a heptane-plus for the heavy-end fraction. The program has the capability of analyzing a sample specified through decane having an undecanes-plus for the heavy-end fraction. The base of the heavy-end compound, for example heptane for heptane-plus, should be entered as zero.

5.5.3 Inputting Physical Parameters

Molecular weight of the liquid phase heavy+: Enter the molecular weight of the heavy-plus fraction , in lb/lb-mole.

Specific gravity of the liquid phase heavy+: Enter the specific gravity (water=1) of the heavy-plus fraction of the liquid stream.

Molecular weight of the vapor phase heavy+: molecular weight of the heavy-plus fraction of the separator gas. Frequently, this information is omitted from routine compositional analysis. In this case, use the properties from the liquid analysis. This information is used with the specific gravity of the vapor phase heavy-plus to compute instantaneous liquid recovery during depletion of volatile oil and gas condensate reservoirs.

Specific gravity of the vapor phase heavy+: Enter the specific gravity (water=1) of the heavy-plus fraction of the separator gas. Frequently, this information is omitted from routine compositional analysis, eventhough the molecular weight of the vapor phase heavy-plus is supplied. In this case, use the properties from the liquid analysis. The user should understand that, in using the properties from the liquid analysis, the computed instantaneous liquid recovery during depletion will be inexact.

System gas-oil ratio: Enter this value, in SCF/STB. The data is required for recombination samples and is irrelevant for well-stream samples. A value of zero (0) should be entered for well-stream systems. The gas-oil ratio is used to determine the proportion of liquid and gas to be recombined to get a full well-stream composition.

System pressure: Enter this value as psia (not psig). The system pressure is used as a starting point in calculating the saturation pressure. A pressure near the expected saturation pressure will decrease computation time.

System Temperature: Enter this value as degree fahrenheit (^{0}F). This will be the temperature at which all calculations will be made, except the standard condition calculation. Normally the reservoir temperature is used.

Experimental bubble point or dew point pressure: Enter this value in psia (not psig) if available; otherwise enter zero (0). Providing this data to the program, may enhance fluid simulation for some samples. This results from using the experimental saturation pressure as the basis for finding methane-heavy-plus interaction factors that will provide for a saturation pressure near the experimental value. However, part of the laboratory analysis this program proposes to eliminate is required to obtain the experimental bubble point pressure.

5.5.4 Inputting computational parameters

Multi-stage separation calculations: Multi-stage separation calculations are available as an option to the user. The user can have up to five stages. If more than one stage is selected the one nearest the wellhead shoud be stage number 1. The sequential stages should be a lower or equal temperature and pressure. After selecting the number of stages, the program will prompt you for the stages.. Enter the pressure in psia, then a comma followed by temperature in fahrenheit.

Equilibrium ratio estimation: Since time is of the essence the choice should be option (2) accelerated successive substitution. Regular successive substitution should be reserve for a

sample which causes the computer to have a runtime system error while converging on equilibrium ratios.

Estimation of Hydrocarbo-Nitrogen Binary and Hydrocarbon-Carbon Dioxide Interaction Parameters: Both options provide satisfactory results for the hydrocarbon-nitrogen and hydrocarbon-carbon dioxide binary interaction parameters. Only the Grabowski-Daubert correlation provides for hydrocarbon-hydrogen sulfide binary interaction parameters, hence it is used for these parameters regardless of the choice made. For consistency, the user may want to choose the Grabowski-Daubert correlation when the sample contains a significant proportion of hydrogen sulfide, but this is not necessary.

Phase Composition Files: The program allows for phase composition files which can later be reviewed or printed. Normally this information is unnecessary, so the user should choose "N" (for no files). Should phase compositions files be desired choose "Y". The program will then prompt you for the flash phase composition file name followed by the differential phase composition file name. There will be no differential phase composition file for the gas condensate program, althought you will be prompted for one anyway. This is done so that the input files are interchangeable between programs. If you should desire phase compositions files , it is highly recommended that you save these files on a separate disk

(unless you happen to have a hard disk). The files are extensive and could overload a disk disk full error. The program allows for a drive specifier in the file name.

Output: The output can either go to the printer or to an output file. If the printer option is chosen the data will be printed at run time and is not saved in a file. The output data is in 132 column format, therefore it is necessary for the printer to be in 132 column mode. This must be done with a DOS command before starting the program. For a standard equipped IBM-PC with an IBM personal computer graphics printer this can be accomplished with the following command:

MODE LPT1:132,8,P

If you have another type of PC-DOS computer or a different type of printer you should consult its manual for the appropriate procedure.

As an alternative, the output can be saved to a file on a disk, and then later reviewed or printed. After selecting the file option you will be prompted for the file name. Although the output file is not very extensive, prudence would dictate that the output should be saved on a seperate disk. This can be done by using a drive specifier in the file name. (See PC-DOS file naming convention section)

5.6 Data Review Editor

After inputting all of the above data or retrieving a data input file, the program displays the data in three parts so that they may be reviewed. The three parts in the order presented for review are mole fractions, input parameters, and computational parameters. Changes can be made as necessary by first signifying with a "Y" when prompted if changes are desired and then identifying the line number of the data you want to change. The program will redisplay the data section with the change made and ask again if changes are desired. When no more changes are desired enter "N" and the program will go on to the next section for review. Changes made in a retrieved data file will not alter the values in the file unless it is resaved.

5.7 Saving Input Data

All input data entered thus far can be saved in a file for later use. It is prudent to do so since it may be necessary to rerun the program with slightly different conditions. It would then be necessary only to substitute the needed changes using the data review editor instead of reentering all the data. To save input data enter "Y" when asked "DO YOU WANT TO SAVE INPUT DATA IN A FILE (Y OR N) ?". The program will then prompt you for the name you wish to give to the input file.

5.8 Changing Computed Heavy-plus Parameters

The correlations of Kessler and Lee are used to estimate the properties of the heavy-plus. The properties consist of boiling point, critical temperature, critical pressure, and acentric factor. The user, at his optiuon, may alter these parameters. If different values are desired, input "Y". You will then be prompted for new values for all four parameters. You must input values when prompted. If the old value is desired, reenter it at the appropriate prompt. The heavy-plus parameters are not saved in the input file since they are computed from other input data.

NOMECLATURE

A	constant defined by eq 2-5
a	attraction parameter
API	API gravity (°API)
B	constant defined by eq 2-6
b	van der Walls covolume (cu ft)
B_g	gas formation volume factor (cu ft/scf)
B_0	oil formation volume factor (BBL/STB)
B_t	total formation volume factor (BBL/STB)
d	solubility parameter
ELC	equivalent liquid content
f	fugacity (psia)
GP	gas phase produced
K	equilibrium ratio
K_w	Watson characterization factor
k_{ij}	binary interaction factor
MV	molar volume
MW	molecular weight (lb/lb mole)
n	total mole fraction
n_L	liquid mole fraction
n_V	vapor mole fraction
P	pressure (psia)

P_c critical pressure (psia)

P_d dew point pressure (psia)

PP plant products

R universal gas constant (10.73 psia cu ft/lb mole °R)

R_s solution gas oil ratio (scf/STB)

SG specific gravity

T temperature (°R)

T_b normal bubble point temperature (°R)

T_c critical temperature (°R)

T_{br} reduced bubble point temperature

TMG total moles of gas

TML total moles of liquid

v molar volume

x liquid mole fraction of a component

y vapor mole fraction of a component

z overall component mole fraction

Z_c critical compressibility factor

Z_L liquid phase compressibility factor

Z_V vapor phase compressibility factor

Greek Leters

α	scaling factor defined by eq 2-13
δ	interaction coefficient
κ	characteristic constant defined by eq 2-14
λ	acceleration parameter
ρ	density (gm/cc)
μ	viscosity (cp)
ω	acentric factor

Subscripts

A	attraction
c	critical property
f	final
g	gas
H+	heavy plus component
i	initial
i, j, k	component i, j, or k
L	liquid
o	oil
R	repulsion
r	reduced property
T	total
V	vapor

APPENDIX A

PVTBO Program Listing

```
C     THOMAS TUFTS
C     PETROLEUM ENGINEERING DEPT.
C
C     PROGRAM PVTOIL(INPUT,OUTPUT,TTY,DIFF,FLSH,TAPE1=TTY,TAPE2=OUTPUT,
C    *TAPE3=DIFF,TAPE4=FLSH)
C
C     PURPOSE:TO COMPUTE PVT PROPERTIES OF A BLACK OIL SYSTEM THAT ARE
C           NORMALLY DETERMINED IN THE LABORATORY.
C
C     INPUT PARAMETERS :
C       THE MINIMUM REQUIRED INPUT DATA CONSIST OF:
C       PR   = RESERVOIR PRESSURE (PSIA)
C       TR   = RESERVOIR TEMPERATURE (DEG.F)
C       Z1   = FLUID COMPOSITION IN TERMS OF GLOBAL MOLE FRACTION
C       THE SUBROUTINES USED ARE:
C       ACEF,BINT,BUBPT,DATA1,DATA2,DENSL,DOUT,DVAP,EQR,FLASH,KCOR,
C       MOLES,PHASEB,QROOT,VISCG,VISCL
C
C     OUTPUT PARAMETERS :
C       APID = API GRAVITY OF LIQUID AT EACH DIFFERENTIAL VAP. STAGE
C       APIF = API GRAVITY OF LIQUID AT EACH FLASH VAP. STAGE
C       BGD  = GAS FORMATION VOLUME FACTOR AT EACH DIFFERENTIAL VAP.
C              STAGE (CU.FT/SCF)
C       BGF  = GAS FORMATION VOLUME FACTOR AT EACH FLASH VAP. STAGE
C              (CU.FT/SCF)
C       BOD  = RELATIVE OIL VOLUME AT EACH DIFFERENTIAL VAP. STAGE
C              (BBL/STB)
C       BOF  = RELATIVE OIL VOLUME AT EACH FLASH VAP. STAGE (BBL/STB)
C       BTD  = TOTAL FORMATION VOLUME FACTOR AT EACH DIFFERENTIAL
C              VAP. STAGE (BBL/STB)
C       BTF  = TOTAL FORMATION VOLUME FACTOR AT EACH FLASH VAP. STAGE
C              (BBL/STB)
C       DENLD = LIQUID DENSITY AT EACH DIFFERENTIAL VAP. STAGE
C              (LB/CU.FT)
C       DENLF = LIQUID DENSITY AT EACH FLASH VAP. STAGE (LB/CU.FT)
C       GOR1 = RATIO OF VOLUME OF GAS AT 14.7 PSIA AND 60 DEG.F TO
C              VOLUME OF OIL AT GIVEN PRESSURE AND TEMPERATURE
C              (SCF/BBL)
C       GOR2 = RATIO OF VOLUME OF GAS AT 14.7 PSIA AND 60 DEG.F TO
C              VOLUME OF OIL AT 14.7 PSIA AND 60 DEG.F
C       NG   = GAS MOLE FRACTION AT EACH FLASH VAP. STAGE
C       NGD  = GAS MOLE FRACTION AT EACH DIFFERENTIAL VAP. STAGE
C       NL   = LIQUID MOLE FRACTION AT EACH FLASH VAP. STAGE
C       NLD  = LIQUID MOLE FRACTION AT EACH DIFFERENTIAL VAP. STAGE
C       NLDM = LIQUID MOLE FRACTION AT EACH DIFFERENTIAL VAP. STAGE
C       NLM  = LIQUID MOLE FRACTION AT EACH FLASH SEPARATION STAGE
C       P    = PRESSURE (PSIA)
C       PB   = CALCULATED BUBBLE POINT PRESSURE (PSIA)
C       PBEXP = EXPERIMENTAL BUBBLE POINT PRESURE )PSIA)
C       PINC = PRESSURE DECREMENT (PSIA)
```

```
C       PP   = PRESSURE AT EACH DIFFERENTIAL OR FLASH VAP. STAGE
C              (PSIA)
C       PSEP = SEPARATOR PRESSURE (PSIG)
C       RSD  = SOLUTION GAS-OIL RATIO AT EACH DIFFERENTIAL VAP. STAGE
C              (SCF/STB)
C       RSF  = SOLUTION GAS-OIL RATIO AT EACH FLASH VAP. STAGE
C              (SCF/STB)
C       RV   = RELATIVE VOLUME, I.E. RATIO OF FLUID VOLUME AT GIVEN
C              FLASH VAP. STAGE TO FLUID VOLUME AT SATURATION
C       RVD  = RELATIVE VOLUME AT EACH DIFFERENTIAL VAP. STAGE
C       SGGD = GAS SPECIFIC GRAVITY AT EACH DIFFERENTIAL VAP. STAGE
C              (AIR=1)
C       SGGF = GAS SPECIFIC GRAVITY AT EACH FLASH VAP. STAGE (AIR=1)
C       SGGS = GAS SPECIFIC GRAVITY DURING MULTI-STAGE SEPARATION
C              (AIR=1)
C       SNL  = LIQUID MOLE FRACTION AT EACH SEPARATOR STAGE
C       SVF  = SEPARATOR OIL VOLUME FACTOR (BBL/STB)
C       TSEP = SEPARATOR TEMPERATURE (DEG.F)
C       VISGD = GAS VISCOSITY AT EACH DIFFERENTIAL VAP. STAGE (CP)
C       VISGF = GAS VISCOSITY AT EACH FLASH VAP. STAGE (CP)
C       VISOD = OIL VISCOSITY AT EACH DIFFERENTIAL VAP. STAGE (CP)
C       VISOF = OIL VISCOSITY AT EACH FLASH VAP. STAGE (CP)
C       VLS  = LIQUID MOLAR VOLUME AT EACH SEPARATOR STAGE
C              (CU.FT/LB-MOLE)
C       ZVD  = GAS COMPRESSIBILITY/DEVIATION FACTOR AT EACH
C              DIFFERENTIAL VAP. STAGE
C       ZVF  = GAS COMPRESSIBILITY/DEVIATION FACTOR AT EACH FLASH
C              VAP. STAGE
C
C     OTHER PARAMETERS :
C       CN1,CN2,ETC = NAME OF COMPONENTS OF COMPUTER FLUID SYSTEM
C                     SAMPLE
C       CPT1,CPT2,ETC = DATA ON PRESSURE,TEMPERATURE AND HEAVY-PLUS
C                       COMPONENT OF COMPUTER FLUID SYSTEM SAMPLE
C       CZ1,CZ2,ETC = COMPONENT GLOBAL MOLE FRACTION OF COMPUTER
C                     FLUID SYSTEM SAMPLE
C       DIF  = DIFFERENCE BETWEEN CALCULATED AND EXPERIMENTAL BUBBLE
C              POINT PRESSURE (PSIA)
C       DLR  = LIQUID MOLE FRACTION REMAINING AT FINAL DIFFERENTIAL
C              VAP. STAGE
C       DLS  = LIQUID MOLE FRACTION AT EACH DIFFERENTIAL VAP.
C              STAGE
C       FLR  = LIQUID MOLE FRACTION REMAINING AT FINAL FLASH VAP.
C              STAGE
C       FLS  = LIQUID MOLE FRACTION AT EACH FLASH VAP. STAGE
C       IT1,IT2,ETC = NO. OF ITERATIONS
C       TML  = TOTAL MOLES OF LIQUID REMAINING AT EACH DIFFERENTIAL
C              VAP. STAGE
C       VD   = LIQUID MOLAR VOLUME AT EACH DIFFERENTIAL VAP. STAGE
C              (CU.FT/LB-MOLE)
```

```
C       VF   = LIQUID MOLAR VOLUME AT EACH FLASH VAP. STAGE
C              (CU.FT/LB-MOLE)
C       VGF1 = GAS VOLUME AT EACH FLASH VAP. STAGE (CU.FT)
C       Z2   = COMPONENT MOLE FRACTION
C       Z3   = COMPONENT MOLE FRACTION
C       Z4   = COMPONENT MOLE FRACTION
C
C     FLAG :
C       ID   = TYPE OF FLUID SYSTEM. ID=1 INDICATES BLACK/VOLATILE
C              OIL; ID=3 INDICATES RETROGRADE CONDENSATE SYSTEM.
C       IBIN = CHOICE OF CORRELATION USED TO ESTIMATE BINARY
C              INTERACTION PARAMETERS (BIP). IBIN=1 INDICATES
C              USE OF GRABOWSKI-DAUBERT CORRELATION FOR H/C-CO2
C              AND H/C-N2 BIP. IBIN=2 INDICATES THE USE OF LAVAL'S
C              CORRELATION FOR SIMILAR BIP.
C       IPB  = USE OF H/C-H/C BINARY INTERACTION PARAMETERS. IPB=1
C              INDICATES ZERO VALUES ARE USED. IPB=2 INDICATES
C              NON-ZERO VALUES ARE USED FROM LAVAL'S CORRELATION
C       ISEP = INDICATES TYPE OF FLUID VAP. CALCULATIONS. ISEP=0
C              INDICATES FLASH VAP. AND ISEP=2 INDICATES
C              DIFFERENTIAL VAP. CALCULATIONS.
C       IPRINT = INDICATES WHETHER OUTPUT ON FLUID COMPOSITION IS
C              FILED OR NOT. IPRINT=Y INDICATES THE OUTPUT IS
C              FILED WHERERS IPRINT=N INDICATES NO FILES.
C       METH = METHOD USED IN EQUILIBRIUM RATIO ESTIMATION.
C              METH=1 INDICATES USE OF SUCCESSIVE SUBSTITUTION AND
C              METH>1 INDICATES USE OF ACCELERATED SUCCESSIVE
C              SUBSTITUTION
C       MLG  = CALCULATIONS USED IN SUB. DENSL. MLG=1 INDICATES
C              CALC. OF LIQUID MOLAR VOLUME AND DENSITY. MLG=2
C              INDICATES CALC. OF GAS SPECIFIC GRAVITY
C       MS   = TEMPERATURE AND PRESSURE CONDITIONS. MS=0 INDICATES
C              CONDITIONS AT GIVEN P & T. MS=1 INDICATES STANDARD
C              CONDITIONS (14.7 PSIA & 60 DEG.F). MS=2 INDICATES
C              CONDITIONS AT 14.7 PSIA & GIVEN TEMP.
C
$DEBUG
      REAL K,NG,NL,NGD,NLD,MWC7,MW,MVOL,NLDM,NLM
      CHARACTER*1 IPRINT
      CHARACTER*9 CN
      CHARACTER*14 FLSH,DIFF,OUTPUT
      COMMON/D1/CN(16)
      COMMON/D2/MW(16),MVOL(16)
      COMMON/D3/W(16),PC(16),TC(16)
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D5/X(16),Y(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D7/ZL,ZV
      COMMON/D8/PB,PBEXP
      COMMON/D9/D(16,16),IBIN,TB(16),IPB
```

```
      COMMON/D10/NG,NL,SUMX,SUMY
      COMMON/D11/ID,MM
      COMMON/D12/ISEP,NCOM,P1
      COMMON/D13/MWC7,SGC7
      COMMON/D14/VL,DENL,SGG,MLG,MS,Z2(16)
      COMMON/D15/IKV,METH
      COMMON/D16/NGD,NLD,XD(16),YD(16),SUMXD,SUMYD
      COMMON/D20/INPUTW,GMWC7,SGGC7,GOR,
     *IOUT,FLSH,DIFF,OUTPUT,PSEP(5),TSEP(5)
      COMMON/D21/IPRINT
      COMMON/D22/NS
      DIMENSION APID(100),APIF(100),BGD(100),BGF(100),BOD(100),BOF(100),
     *BTD(100),BTF(100),NLDM(100),NLM(100),RSD(100),RSF(100),SGGD(100),
     *SGGF(100),VD(100),VF(100),VISGD(100),VISGF(100),VISOD(100),
     *VISOF(100),ZVD(100),ZVF(100),DENLD(100),DENLF(100),AVD(100),
     *TML(100),Z4(16),AV(100),VGF1(100),DIF(20),
     *SNL(10),VLS(10),SGGS(10),GOR1(10),GOR2(10),SVF(10)
      DATA R/10.731/
      OPEN (1,FILE='CON')
      CALL EXDATA
      CALL INPUT
      OPEN (2,FILE=OUTPUT,STATUS='NEW')
      IF (IPRINT.EQ.'Y'.OR.IPRINT.EQ.'y') THEN
      OPEN (3,FILE=DIFF,STATUS='NEW')
      OPEN (4,FILE=FLSH,STATUS='NEW')
      ENDIF
C     SELECT DESIRED METHOD OF BINARY INTERACTION PARAMETERS ESTIMATION
    5 WRITE(1,1011)
      WRITE(2,1011)
      CALL DATA1
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'            ****************************'
      WRITE(*,*)'            *** PROGRAM IN PROGRESS ***'
      WRITE(*,*)'            ***    PLEASE WAIT.    ***'
      WRITE(*,*)'            ****************************'
      WRITE(*,*)'            ****** 5-30 MINUTES *******'
      WRITE(*,*)'            ****************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      IPB=1
   10 WRITE(2,1012)
      IF (IBIN.EQ.1) THEN
        WRITE(2,1017)
      ELSE
        WRITE(2,1018)
      ENDIF
      IF (METH.EQ.1) THEN
```

```
      WRITE(2,1015)
    ELSE
      WRITE(2,1016)
    ENDIF
 16 CALL BINT
    WRITE(1,1031)TR,PR
    WRITE(2,1031)TR,PR
    IF (PBEXP.LT.1.0) THEN
      WRITE(1,1032)
      WRITE(2,1032)
    ELSE
      WRITE(1,1033)PBEXP
      WRITE(2,1033)PBEXP
    ENDIF
    WRITE(1,1034)
    WRITE(2,1034)
    DO 18 I=1,16
         IF (Z1(I).LT.1.E-25) GO TO 18
           WRITE(1,1035)CN(I),Z1(I)
           WRITE(2,1035)CN(I),Z1(I)
 18 CONTINUE
    IF (Z1(16).LT.1.E-25) GO TO 19
    WRITE(1,1036)MWC7,SGC7
    WRITE(2,1036)MWC7,SGC7
 19 IF (PBEXP.GT.1.0) GO TO 20
C   DETERMINE TYPE OF FLUID.
    CALL PHASEB
    IF ((ID.EQ.0).OR.(ID.GT.2)) GO TO 400
C   CALCULATE BUBBLE POINT PRESSURE (NO EXPERIMENTAL VALUE GIVEN).
    P=14.7
    CALL BUBPT
    GO TO 50
C   CALCULATE BUBBLE POINT PRESSURE (EXPERIMENTAL VALUE GIVEN).
 20 P=PBEXP
    CALL BUBPT
    IF ((ABS(PBEXP-PB).LE.25.0).OR.(Z1(16).LT.1.E-25)) GO TO 50
C   MATCH THE CALCULATED BUBBLE POINT PRESSURE TO THE EXPERIMENTAL
C   VALUE BY VARYING THE METHANE-HEAVY PLUS BINARY INTERACTION
C   FACTOR.
 30 DMIN=0.1
    DO 40 I=1,5
         IF (I.EQ.1) GO TO 32
         D(4,16)=D(4,16)+0.01
         D(16,4)=D(16,4)+0.01
         CALL BUBPT
 32      DIF(I)=PB-PBEXP
         IF (I.EQ.1) GO TO 35
         IF (ABS(DIF(I)).GE.ABS(DMIN)) GO TO 45
 35      DMIN=DIF(I)
         BIN=D(4,16)
```

```
          WRITE(1,1007)BIN,DMIN,PB
   40 CONTINUE
      IF (IPB.EQ.2) GO TO 45
      IF ((PBEXP-PB-50.).GT.0.) THEN
                IPB=2
                CALL BINT
                GO TO 30
      ENDIF
   45 D(4,16)=BIN
      D(16,4)=BIN
      PB=PBEXP+DMIN
   50 WRITE(1,1150)PB
      WRITE(2,1150)PB
      DO 51 I=1,16
            Z3(I)=Z1(I)
            Z4(I)=Z1(I)
   51 CONTINUE
C     PERFORM DIFFERENTIAL AND FLASH CALCULATIONS.
   52 P=PB
      PP=PB
      NS=0
      IF (PB.LE.1000.) THEN
        PINC=50.
      ELSE
        PINC=100.
      ENDIF
      DO 235 IT=1,100
            IF (IT.EQ.1) GO TO 196
            DO 194 I=1,16
                  Z1(I)=Z3(I)
  194       CONTINUE
C           DIFFERENTIAL SEPARATION OF FLUID.
  196       IT3=1
            CALL KCOR
            ISEP=2
  201       CALL DVAP
            DO 199 I=1,16
                  X(I)=XD(I)
                  Y(I)=YD(I)
  199       CONTINUE
            CALL EQR
            IF (ABS(SUMER).LE.1.E-5) GO TO 204
            IF (IT3.GE.100) GO TO 203
            IT3=IT3+1
            GO TO 201
  203       WRITE(1,1060)IT3
            WRITE(2,1060)IT3
            GO TO 400
  204       IF (IPRINT.EQ.'N'.OR.IPRINT.EQ.'n') GO TO 197
            IF (IT.GT.1) GO TO 205
```

```
      WRITE(3,1011)
205   P1=PP
      CALL DOUT
197   MLDM(IT)=MLD
      IF (MLD.LE.0.) GO TO 207
C     CALCULATE LIQUID MOLAR VOLUME AND DENSITY OF THE
C     DIFFERENTIALLY SEPARATED FLUID.
      DO 206 I=1,16
           Z2(I)=XD(I)
           Z3(I)=XD(I)
206   CONTINUE
      MLG=1
      CALL DENSL
      VD(IT)=VL
      DENLD(IT)=DENL
      GO TO 208
207   VD(IT)=0.
      DENLD(IT)=0.
208   IF (MLD.GE.1.) GO TO 210
C     CALCULATE GAS SPECIFIC GRAVITY AND VISCOSITY OF THE
C     DIFFERENTIALLY SEPARATED FLUID.
      DO 209 I=1,16
           Z2(I)=YD(I)
209   CONTINUE
      MLG=2
      CALL DENSL
      GO TO 211
210   ZV=0.
      SGG=0.
211   ZVD(IT)=ZV
      SGGD(IT)=SGG
      CALL VISCG(P,T,SGG,ZV,VISG)
      VISGD(IT)=VISG
C     FLASH SEPARATION OF THE FLUID.
      DO 215 I=1,16
           Z1(I)=Z4(I)
215   CONTINUE
      IT4=1
      CALL KCOR
      ISEP=0
219   CALL FLASH
      CALL MOLES
      CALL EQR
      IF (ABS(SUMER).LE.1.E-5) GO TO 224
      IF (IT4.GE.100) GO TO 223
      IT4=IT4+1
      GO TO 219
223   WRITE(1,1060)IT4
      WRITE(2,1060)IT4
      GO TO 400
```

```
  224       IF (IPRINT.EQ.'N'.OR.IPRINT.EQ.'n') GO TO 195
            IF (IT.GT.1) GO TO 225
            WRITE(4,1011)
  225       P1=PP
            CALL DOUT
  195       NLM(IT)=1.-NG
            IF (NG.GE.1.) GO TO 227
C           CALCULATE LIQUID MOLAR VOLUME AND DENSITY OF THE
C           FLASHED FLUID.
            DO 226 I=1,16
                 Z2(I)=X(I)
  226       CONTINUE
            MLG=1
            CALL DENSL
            VF(IT)=VL
            DENLF(IT)=DENL
            GO TO 228
  227       VF(IT)=0.
            DENLF(IT)=0.
  228       IF (NG.LE.0.) GO TO 230
C           CALCULATE GAS SPECIFIC GRAVITY AND VISCOSITY OF THE
C           FLASHED FLUID.
            DO 229 I=1,16
                 Z2(I)=Y(I)
  229       CONTINUE
            MLG=2
            CALL DENSL
            GO TO 231
  230       ZV=0.
            SGG=0.
  231       ZVF(IT)=ZV
            VGF1(IT)=(1.-NLM(IT))*ZV*R*(T+460.)/P
            SGGF(IT)=SGG
            CALL VISCG(P,T,SGG,ZV,VISG)
            VISGF(IT)=VISG
            IF (NS.EQ.1) GO TO 236
            P=PP-PINC/2.
            PP=PP-PINC
            IF (PP.LT.100.) GO TO 232
            GO TO 235
  232       P=14.7
            T=60.
            NS=1
  235       CONTINUE
C     CALCULATE OIL FORMATION VOLUME FACTOR AND SOLUTION GAS-OIL RATIO
C     OF THE DIFFERENTIALLY SEPARATED AND FLASHED FLUID.
  236 P=PB
      T=TR
      DLS=1.
      DLR=1.
```

```
C     CALCULATE TOTAL LIQUID MOLES REMAINING AFTER DIFFERENTIAL
C     SEPARATION.
      DO 237 I=1,IT
           DLR=DLR*MLDM(I)
  237 CONTINUE
      DO 238 I=1,IT
           DLS=DLS*MLDM(I)
           TML(I)=DLS
           BOD(I)=VD(I)*DLS/(VD(IT)*DLR)
           BOF(I)=VF(I)*MLM(I)/(VF(IT)*MLM(IT))
  238 CONTINUE
      DO 241 I=1,IT
           RSD(I)=(TML(I)-TML(IT))*2130./(VD(IT)*DLR)
           RSF(I)=(MLM(I)-MLM(IT))*2130./(VF(IT)*MLM(IT))
  241 CONTINUE
      RSD(IT)=0.
      VISOD(1)=0.
      VISOF(1)=0.
      ZVD(1)=0.
      ZVF(1)=0.
      SGOD(1)=0.
      SGOF(1)=0.
      DENSO=DENLD(IT)
      DENSF=DENLF(IT)
C     CALCULATE LIQUID VISCOSITY.
      CALL VISCL(DENSO,T,RSD,VISOD,IT)
      CALL VISCL(DENSF,T,RSF,VISOF,IT)
C     CALCULATE GAS FORMATION VOLUME FACTOR,TOTAL FORMATION VOLUME
C     FACTOR,OIL RELATIVE DENSITY AND DEGREE API,AND RELATIVE VOLUME
C     OF THE DIFFERENTIALLY SEPARATED FLUID.
      P=PB
      T=TR
      MS=0
      WRITE(1,1310)
      WRITE(2,1310)
      WRITE(1,1320)
      WRITE(2,1320)
      DO 245 I=1,IT
           BGD(I)=0.0282*ZVD(I)*(T+460.)/P
           BTD(I)=BOD(I)+(BGD(I)*(RSD(1)-RSD(I)))/5.615
           DENLD(I)=DENLD(I)/62.4
           APID(I)=141.5/DENLD(I)-131.5
           AVD(I)=(VF(I)*TML(I)+(1.-TML(I))*ZVD(I)*R*(T+460.)/P)/VF(1)
           WRITE(1,1330)P,T,RSD(I),BOD(I),BTD(I),APID(I),DENLD(I),
     *     ZVD(I),BGD(I),SGOD(I),VISOD(I),VISGD(I),AVD(I)
           WRITE(2,1330)P,T,RSD(I),BOD(I),BTD(I),APID(I),DENLD(I),
     *     ZVD(I),BGD(I),SGOD(I),VISOD(I),VISGD(I),AVD(I)
           IF (MS.EQ.1) GO TO 249
           IF (I.EQ.IT-1) GO TO 244
           P=P-PINC
```

```
            GO TO 245
  244       P=14.7
            T=60.
            MS=1
  245 CONTINUE
C     CALCULATE GAS FORMATION VOLUME FACTOR,TOTAL FORMATION VOLUME
C     FACTOR,OIL RELATIVE DENSITY AND DEGREE API,AND RELATIVE VOLUME
C     OF THE FLASHED FLUID.
  249 P=PB
      T=TR
      MS=0
      WRITE(1,1315)
      WRITE(2,1315)
      WRITE(1,1320)
      WRITE(2,1320)
      DO 247 I=1,IT
            BGF(I)=0.0282*ZVF(I)*(T+460.)/P
            BTF(I)=BOF(I)+(BGF(I)*(RSF(1)-RSF(I)))/5.615
            DENLF(I)=DENLF(I)/62.4
            APIF(I)=141.5/DENLF(I)-131.5
            AV(I)=(VF(I)*MLM(I)+VGF1(I))/(VF(1)*MLM(1))
            WRITE(1,1330)P,T,RSF(I),BOF(I),BTF(I),APIF(I),DENLF(I),
     *      ZVF(I),BGF(I),SGGF(I),VISOF(I),VISGF(I),AV(I)
            WRITE(2,1330)P,T,RSF(I),BOF(I),BTF(I),APIF(I),DENLF(I),
     *      ZVF(I),BGF(I),SGGF(I),VISOF(I),VISGF(I),AV(I)
            IF (MS.EQ.1) GO TO 271
            IF (I.EQ.IT-1) GO TO 246
            P=P-PINC
            GO TO 247
  246       P=14.7
            T=60.
            MS=1
  247 CONTINUE
C     MULTI-STAGE SEPARATION SIMULATION:
C     - FLASH CALCULATIONS ARE PERFORMED AT GIVEN PRESSURE AND
C     - TEMPERATURE OF EACH SEPARATOR.
  271 DO 274 I=1,16
            Z1(I)=Z4(I)
  274 CONTINUE
  275 MS=0
      IF (NS.EQ.0) GO TO 400
      WRITE(2,1209)
      DO 320 IS=1,NS+1
            IT6=1
            IF (MS.EQ.1) GO TO 305
            P=PSEP(IS)
            T=TSEP(IS)
            IF ((P.LT.1.).AND.(T.LT.1.)) GO TO 400
            PSEP(IS)=P-14.7
            TSEP(IS)=T
```

```
  305       CALL KCOR
            ISEP=0
  273       CALL FLASH
            CALL MOLES
            CALL EQR
            IF (ABS(SUMER).LE.1.E-5) GO TO 280
            IF (IT6.GE.100.) GO TO 278
            IT6=IT6+1
            GO TO 273
  278       WRITE(1,1060)IT6
            WRITE(2,1060)IT6
            GO TO 400
  280       IF (IPRINT.EQ.'N'.OR.IPRINT.EQ.'n') GO TO 290
            IF (IS.GT.1) GO TO 285
            WRITE(2,1209)
  285       P1=P
            CALL DOUT
  290       SNL(IS)=1.-NG
C           CALCULATE LIQUID MOLAR VOLUME AND DENSITY.
            DO 300 I=1,16
                 Z1(I)=X(I)
                 Z2(I)=X(I)
  300       CONTINUE
            MLG=1
            CALL DENSL
            VLS(IS)=VL
            IF (MS.EQ.0) GO TO 307
            DEN0=DENL
  307       IF (NG.LE.0.) GO TO 315
C           CALCULATE GAS SPECIFIC GRAVITY.
            DO 310 I=1,16
                 Z2(I)=Y(I)
  310       CONTINUE
            MLG=2
            CALL DENSL
            GO TO 316
  315       SGG=0.
  316       SGGS(IS)=SGG
            IF (MS.EQ.1) GO TO 330
            IF (IS.NE.NS) GO TO 320
            P=14.7
            T=60.
            MS=1
  320 CONTINUE
C     CALCULATE OIL FORMATION VOLUME FACTOR AND SOLUTION GAS-OIL
C     RATIO.
  330 FLS=1.
      FLR=1.
      DO 340 I=1,IS
            FLR=FLR*SNL(I)
```

```
340 CONTINUE
    DO 350 I=1,NS
          FLS=FLS*SNL(I)
          GOR1(I)=(1.-SNL(I))*2130./(SNL(I)*ULS(I))
          GOR2(I)=(1.-SNL(I))*2130./(ULS(IS)*FLR)
          SUF(I)=ULS(I)*FLS/(ULS(IS)*FLR)
350 CONTINUE
    TORPI=141.5*62.4/DENO-131.5
    FUF=ULS(1)*SNL(1)/(ULS(IS)*FLR)
    WRITE(1,1220)
    WRITE(2,1220)
    DO 380 I=1,NS
    IF (I.EQ.NS) GO TO 370
    WRITE(1,1230)PSEP(I),TSEP(I),GOR1(I),GOR2(I),SUF(I),SGOS(I)
    WRITE(2,1230)PSEP(I),TSEP(I),GOR1(I),GOR2(I),SUF(I),SGOS(I)
    GO TO 380
370       WRITE(1,1240)PSEP(I),TSEP(I),GOR1(I),GOR2(I),TORPI,FUF,
   *      SUF(I),SGGS(I)
          WRITE(2,1240)PSEP(I),TSEP(I),GOR1(I),GOR2(I),TORPI,FUF,
   *      SUF(I),SGOS(I)
380 CONTINUE
    WRITE(1,1260)
    WRITE(2,1260)
400 CONTINUE
500 STOP

1011 FORMAT(/20X,26('*'),/20X,'*',1X,'BLACK OIL PVT ANALYSIS',1X,'*',
    */20X,26('*'))
1012 FORMAT(/3X,'METHOD/CORRELATION USED',10X,'PURPOSE',/3X,23('-'),
    *10X,7('-'))
1017 FORMAT(3X,'GRABOWSKI-DAUBERT',16X,'N2-H/C,CO2-H/C AND H2S-H/C BINA
    *RY',/,36X,'INTERACTION PARAMETERS ESTIMATION')
1018 FORMAT(3X,'LAVAL',28X,'N2-H/C AND CO2-H/C BINARY',/,36X,
    *'INTERACTION PARAMETERS ESTIMATION',/3X,'GRABOWSKI-DAUBERT',
    *16X,'H2S-H/C BINARY INTERACTION',/,36X,'PARAMETERS ESTIMATION')
1015 FORMAT(3X,'SUCCESSIVE SUBSTITUTION',10X,'ITERATIVE ESTIMATION OF K
    *-VALUES')
1016 FORMAT(3X,'ACCD. SUCCESSIVE SUBSTITUTION',4X,'ITERATIVE ESTIMATION
    * OF K-VALUES')
1060 FORMAT(88(1H-),/3X,'K-VALUES DO NOT CONVERGE AFTER = ',1X,I3,2X,
    *'ITERATIONS.')
1209 FORMAT(1H1,/3X,'MULTI-STAGE SEPARATOR CALCULATIONS',/3X,
    *'-----------------------------------')
1210 FORMAT(//3X,'MULTI-STAGE SEPARATION CALCULATIONS:',/6X,
    *'TO PERFORM SUCH CALCULATIONS,',/6X,'TYPE THE NO. OF STAGES OF SEP
    *ARATORS (INTEGER FORM).',/6X,'ELSE,TYPE INTEGER 0',/)
1220 FORMAT(/1X,'SEPARATOR',11X,'GAS/OIL',2X,'GAS/OIL',2X,'TANK OIL',
    *2X,'FORMATION',2X,'SEPARATOR',/1X,'PRESSURE',4X,'TEMP.',4X,
    *'RATIO',4X,'RATIO',4X,'GRAVITY',4X,'VOLUME',5X,'VOLUME',7X,'GAS',
    */2X,'(PSIG)',4X,'(DEG.F)',4X,'(1)',6X,'(2)',4X,'(DEG.API)',2X,
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     *'FACTOR(3)',2X,'FACTOR(4)',3X,'GRAVITY',/)
1230 FORMAT(2X,F5.1,6X,F4.0,5X,F5.0,4X,F5.0,27X,F5.3,6X,F5.3)
1240 FORMAT(2X,F5.1,6X,F4.0,5X,F5.0,4X,F5.0,5X,F4.1,7X,F5.3,6X,F5.3,
     *6X,F5.3)
1260 FORMAT(/3X,'NOTE',/3X,'----',/3X,'(1) GOR IN SCF/BBL',/3X,
     *'(2) GOR IN SCF/STB',/3X,'(3) BBLS OF OIL AT SATURATION PRESSURE
     *PER STB',/3X,'(4) BBLS OF OIL AT GIVEN P&T PER STB')
1150 FORMAT(/3X,'CALC.BUBBLE POINT PRESSURE = ',F10.2,2X,'PSIA')
1031 FORMAT(/3X,'INITIAL RESERVOIR CONDITIONS AND COMPOSITION (GIVEN)',
     */3X,'-------------------------------------------------',/3X,
     *'RESERVOIR TEMPERATURE = ',F5.1,3X,'DEG.F',/3X,
     *'RESERVOIR PRESSURE    = ',F7.2,2X,'PSIA')
1032 FORMAT(3X,'BUBBLE POINT PRESSURE (EXPT.) = NOT GIVEN')
1033 FORMAT(3X,'BUBBLE POINT PRESSURE (EXPT.) = ',2X,F7.2,2X,'PSIA')
1034 FORMAT(//3X,'COMPONENT',18X,
     *'MOLE FRACTION',/3X,'---------',18X,'-----------')
1035 FORMAT(3X,A9,20X,F7.5)
1036 FORMAT(/3X,'HEAVY-PLUS:MOLECULAR WEIGHT = ',F4.0,
     */16X,'SPECIFIC GRAVITY = ',F7.5,/)
1310 FORMAT(1H1,/51X,29('*'),/51X,'*',1X,'DIFFERENTIAL VAPORIZATION',
     *1X,'*',/51X,29('*'))
1315 FORMAT(1H1,/55X,22('*'),/55X,'*',1X,'FLASH VAPORIZATION',1X,'*',
     */55X,22('*'))
1320 FORMAT(132(1H-),/23X,'SOLN',8X,'OIL',7X,'TOTAL',6X,'DEG',6X,'OIL',
     *7X,'Z',11X,'GAS',8X,'GAS',6X,'OIL',6X,'GAS',4X,'RELATIVE',/2X,
     *'PRES',6X,'TEMP',8X,'GOR',8X,'FVF',8X,'FVF',7X,'API',4X,'DENSITY',
     *3X,'FACTOR',8X,'FVF',6X,'GRAVITY',4X,'VISC',5X,'VISC',4X,'VOLUME',
     */1X,'(PSIA)',4X,'(DEG.F)',3X,'(SCF/STB)',2X,'(BBL/STB)',2X,
     *'(BBL/STB)',11X,'(GM/CC)',13X,'(CU.FT/SCF)',2X,'(AIR=1)',4X,
     *'(CP)',5X,'(CP)',/)
1330 FORMAT(1X,F6.1,5X,F5.1,5X,F6.1,6X,F5.3,4X,F7.4,4X,F5.1,4X,F6.4,
     *4X,F5.3,6X,F6.4,6X,F5.3,5X,F4.2,4X,F6.4,3X,F6.3)
1007 FORMAT(/3X,'WHEN METHANE-HEAVY+ INTERACTION FACTOR = ',F6.4,
     */20X,'PRES.DIFFERENCE = ',F8.2,2X,'PSIA',/20X,
     *'EST.BUBBLE POINT PRES. = ',F7.2,2X,'PSIA')
      END
```

```
      SUBROUTINE ACEF
C
C     PURPOSE : ESTIMATE PROPERTIES OF HEAVY-PLUS USING
C               KESSLER-LEE CORRELATIONS.
C
C     INPUT PARAMETERS :
C       MWC7 = MOLECULAR WEIGHT OF HEAVY-PLUS (LB/LB-MOLE)
C       SGC7 = SPECIFIC GRAVITY OF HEAVY-PLUS (WATER=1)
C     OUTPUT PARAMETERS :
C       MVOL(16)= MOLAR VOLUME OF HEAVY-PLUS (CU.FT/LB-MOLE)
C       PC(16) = CRITICAL PRESSURE OF HEAVY-PLUS (PSIA)
C       TB(16) = NORMAL BOILING POINT TEMP. OF HEAVY-PLUS (DEG.R)
C       TC(16) = CRITICAL TEMP. OF HEAVY-PLUS (DEG.F)
C       W(16)  = ACENTRIC FACTOR OF HEAVY-PLUS
C     OTHER PARAMETERS :
C       KW  = WATSON CHARACTERIZATION FACTOR
C       TBR = REDUCED BOILING POINT TEMP.,TB/TC
C
      COMMON/D2/MW(16),MVOL(16)
      COMMON/D3/W(16),PC(16),TC(16)
      COMMON/D9/D(16,16),IBIN,TB(16),IPB
      COMMON/D11/ID,MM
      COMMON/D13/MWC7,SGC7
      REAL KW,MWC7,MW,MVOL
      CHARACTER*1 M1
C     ESTIMATE NORMAL BOILING POINT TEMPERATURE.
      IT=1
      TBC=660.
   10 F=MWC7+12272.6-9486.4*SGC7-(4.6523-3.3287*SGC7)*TBC-(1.3437-1.0358
     **SGC7-.027653*SGC7**2)*1.E7/TBC+(720.79-555.6139*SGC7-14.83386
     **SGC7**2)*1.E7/(TBC**2)-(1.8828-1.52285*SGC7+.04191*SGC7**2)*1.E12
     */(TBC**3)+(181.98-147.1891*SGC7+4.05087*SGC7**2)*1.E12/(TBC**4)
      FP=-4.6523+3.3287*SGC7+(1.3437-1.0358*SGC7-.027653*SGC7**2)*1.E7
     */(TBC**2)-(1441.58-1111.23*SGC7-29.6677*SGC7**2)*1.E7/(TBC**3)+
     *(5.6494-4.5685*SGC7+.12573*SGC7**2)*1.E12/(TBC**4)-(727.92-588.756
     **SGC7+16.2035*SGC7**2)*1.E12/(TBC**5)
      IF (ABS(F).LT.1.E-3) GO TO 20
      TBC=TBC-F/FP
      IF (IT.GE.100) GO TO 50
      IT=IT+1
      GO TO 10
C     ESTIMATE CRITICAL TEMPERATURE AND PRESSURE.
   20 TCC=-118.3+811.*SGC7+(.4244+.1174*SGC7)*TBC+(.4669-3.2623*SGC7)
     **1.E5/TBC
      PC1=8.3634-.0566/SGC7-(.24244+2.2898/SGC7+.11857/(SGC7**2))*1.E-3
     **TBC+(1.4685+3.648/SGC7+.47227/(SGC7**2))*1.E-7*TBC**2-(.42019+
     *1.6977/(SGC7**2))*1.E-10*TBC**3
      PCC=EXP(PC1)
C     ESTIMATE ACENTRIC FACTOR.
      TBR=TBC/(TCC+460.)
```

```
      IF (TBR.GT.0.8) GO TO 30
      A1=ALOG(14.7/PCC)-5.927+14+6.09648/TBR+1.28862*ALOG(TBR)-.169347
     **TBR**6
      A2=15.2518-15.6875/TBR-13.4721*ALOG(TBR)+.43577*TBR**6
      WC=A1/A2
      GO TO 40
   30 KW=TBC**(1./3.)/SGC7
      WC=-7.904+.1352*KW-.007465*KW**2+8.359*TBR+(1.408-.01063*KW)/TBR
   40 TBC=TBC-460.
      MW(16)=MWC7
      MVOL(16)=MWC7/(62.4*SGC7)
      WR16=(MWC7+28.2608)/347.826
      WRITE(1,100)
      WRITE(2,100)
      WRITE(1,120)TBC,TCC,PCC,WC
      WRITE(2,120)TBC,TCC,PCC,WC
      WRITE(1,130)WR16
   41 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'         ************************************************
     ****************'
      WRITE(*,*)'         *   DO YOU WANT TO USE DIFFERENT HEAVY-PLUS PA
     *RAMETERS ?     *'
      WRITE(*,*)'         *           (I.E. BOILING POINT, CRITICAL TEMP
     *ERATURE,       *'
      WRITE(*,*)'         *             CRITICAL PRESSURE, AND ACENTRIC
     *FACTOR)        *'
      WRITE(*,*)'         ************************************************
     ****************'
      WRITE(*,*)'                              *       (Y) YES       *'
      WRITE(*,*)'                              *                     *'
      WRITE(*,*)'                              *       (N) NO        *'
      WRITE(*,*)'                              ***********************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,'(A)')M1
      IF (M1.NE.'Y'.AND.M1.NE.'N') THEN
      IF (M1.NE.'y'.AND.M1.NE.'n') GO TO 41
      ENDIF
      IF (M1.EQ.'Y'.OR.M1.EQ.'y') GO TO 45
   43 TB(16)=TBC+460.
      TC(16)=TCC
      PC(16)=PCC
      W(16)=WC
      GO TO 60
   45 WRITE(*,*)
      WRITE(*,*)
```

```
      WRITE(*,*)
      WRITE(*,'(A\)')' HEAVY+ BOILING POINT -->'
      READ(*,*)TBA
      WRITE(*,'(A\)')' HEAVY+ CRITICAL TEMPERATURE -->'
      READ(*,*)TCA
      WRITE(*,'(A\)')' HEAVY+ CRITICAL PRESSURE -->'
      READ(*,*)PCA
      WRITE(*,'(A\)')' HEAVY+ ACENTRIC FACTOR -->'
      READ(*,*)WA
      TB(16)=TBA+460.
      TC(16)=TCA
      PC(16)=PCA
      W(16)=WA
      WRITE(1,160)
      WRITE(2,160)
      WRITE(1,120)TBA,TCA,PCA,WA
      WRITE(2,120)TBA,TCA,PCA,WA
      GO TO 60
   50 WRITE(1,110)
   60 RETURN

  100 FORMAT(//3X,'ESTIMATED PROPERTIES OF HEAVY-PLUS ARE :')
  120 FORMAT(/10X,'NORMAL BOILING POINT TEMP. = ',F7.2,2X,
     *'DEG.F',/10X,'CRITICAL TEMPERATURE = ',2X,F7.2,2X,'DEG.F',
     */10X,'CRITICAL PRESSURE    = ',2X,F7.2,2X,'PSIA',
     */10X,'ACENTRIC FACTOR      = ',2X,F6.4)
  110 FORMAT(/3X,'NO BOILING POINT TEMP. AVAILABLE FROM SUB.ACEF')
  130 FORMAT(/3X,'HEAVY-PLUS ACENTRIC FACTOR VALUE FROM MOL.WT.RELATIONS
     *HIP IS = ',1X,F8.6)
  160 FORMAT(/3X,'NEW HEAVY-PLUS PARAMETERS TO BE USED ARE :')
      END
```

```
      SUBROUTINE BINT
C
C     PURPOSE : ESTIMATE BINARY INTERACTION FACTORS.
C
C     INPUT PARAMETERS :
C       MW  = MOLECULAR WEIGHT (LB/LB-MOLE)
C       SOL = HILDEBRAND'S SOLUBILITY PARAMETER
C       TB  = NORMAL BOILING POINT TEMP. (DEG.R)
C     OUTPUT PARAMETERS :
C       D   = BINARY INTERACTION PARAMETER
C     FLAG :
C       IBIN  = CHOICE OF CORRELATION USED TO ESTIMATE BINARY
C               INTERACTION PARAMETERS (BIP). IBIN=1 INDICATES
C               USE OF GRABOWSKI-DAUBERT CORRELATION FOR H/C-CO2
C               AND H/C-N2 BIP. IBIN=2 INDICATES THE USE OF LAWAL'S
C               CORRELATION FOR SIMILAR BIP.
C
      COMMON/D2/MW(16),MVOL(16)
      COMMON/D9/D(16,16),IBIN,TB(16),IPB
      DIMENSION SOL(16)
      REAL MW
      DATA SOL/4.44,8.8,7.12,5.68,6.05,6.4,6.73,6.634,7.02,7.02,7.266,
     *7.43,7.551,7.649,7.722,7.55/
      D(1,1)=.0
      D(1,2)=.14
      D(1,3)=.068
      D(2,1)=.14
      D(2,2)=.0
      D(2,3)=.102
      D(3,1)=.068
      D(3,2)=.102
      D(3,3)=.0
      D(1,16)=.16
      D(2,16)=.04
      D(3,16)=.1369
      D(16,1)=.16
      D(16,2)=.04
      D(16,3)=.1369
      IF (IBIN.GT.1) GO TO 21
C     ESTIMATE BINARY INTERACTION PARAMETERS OF CO2,N2 AND H2S
C     SYSTEM USING GRABOWSKI-DAUBERT CORRELATION.
      DO 10 I=4,15
           SOL1=ABS(SOL(I)-SOL(3))
           DUM1=.1294+.0292*SOL1-.0222*SOL1**2
           D(3,I)=DUM1
           D(I,3)=DUM1
   10 CONTINUE
      DO 20 I=4,15
           SOL2=ABS(SOL(I)-SOL(1))
           DUM2=-.0836+.1055*SOL2-.01*SOL2**2
```

```
          D(1,I)=DUM2
          D(I,1)=DUM2
   20 CONTINUE
   21 DO 30 I=4,15
      DUM3=.0178+.0244*ABS(SOL(I)-SOL(2))
      D(2,I)=DUM3
      D(I,2)=DUM3
   30 CONTINUE
      IF (IPB.EQ.1) GO TO 40
C     CALCULATE HYDROCARBON-HYDROCARBON BINARY INTERACTION
C     PARAMETERS.
      DO 35 I=4,16
      DO 35 J=4,16
          DIFF=ABS(MW(I)-MW(J))
          IF (I.GT.J) GO TO 32
          TB1=TB(I)
          GO TO 33
   32     TB1=TB(J)
   33     DUM4=1.8*ALOG(DIFF+1.)**0.92/TB1
          D(I,J)=DUM4
   35 CONTINUE
      GO TO 37
   40 DO 36 I=4,16
      DO 36 J=1,16
          D(I,J)=0.
   36 CONTINUE
   37 IF (IBIN.EQ.1) GO TO 60

C     CALCULATE N2-HYDROCARBONS BINARY INTERACTION PARAMETERS.
      DO 38 I=4,16
          DIFF1=ABS(MW(I)-MW(1))
          DUM5=1.8*ALOG(DIFF1+1.)**1.6/TB(1)
          D(I,1)=DUM5
          D(1,I)=DUM5
   38 CONTINUE

C     CALCULATE CO2-HYDROCARBONS BINARY INTERACTION PARAMETERS.
      DO 41 I=4,16
          DIFF2=ABS(MW(I)-MW(3))
          DUM6=1.8*ALOG(DIFF2+1.)**2.5/TB(3)
          D(I,3)=DUM6
          D(3,I)=DUM6
   41 CONTINUE
   60 RETURN
      END
```

```
      SUBROUTINE BUBPT
C
C     PURPOSE : CALCULATES BUBBLE POINT PRESSURE USING THE METHOD OF
C               SUMMATION OF Z1*K = 1.
C
C     INPUT PARAMETERS :
C       K    = EQUILIBRIUM RATIO
C       Z1   = COMPONENT GLOBAL MOLE FRACTION
C     OUTPUT PARAMETERS :
C       PB   = BUBBLE POINT PRESSURE (PSIA)
C     FLAG :
C       ISEP = INDICATES TYPE OF FLUID VAP. CALCULATIONS. ISEP=0
C              INDICATES FLASH VAP. AND ISEP=2 INDICATES
C              DIFFERENTIAL VAP. CALCULATIONS.
C
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D8/PB,PBEXP
      COMMON/D12/ISEP,NCOM,P1
      REAL K
C     CALCULATES K-VALUE OF EACH COMPONENT.
      LB=1
    5 ITE=1
      CALL KCOR
      ISEP=0
    7 CALL FLASH
      CALL MOLES
      CALL EQR
      IF (ABS(SUMER).LE.1.E-5) GO TO 18
      IF (ITE.GE.100) GO TO 60
      ITE=ITE+1
      GO TO 7
   18 F=0.
C     CALCULATES SUMMATION OF Z1*K.
      DO 20 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 20
           F=F+Z1(I)*K(I)
   20 CONTINUE
      IF (LB.EQ.2) GO TO 30
      IF (F.GT.1.) GO TO 25
      GO TO 40
   25 P=P+100.
      GO TO 5
   30 IF (F.GE.1.) GO TO 50
   40 P=P-10.
      LB=2
      IF (P.GT.14.7) GO TO 5
      GO TO 65
   50 DO 58 INC=1,10
           P=P+1.
```

```
      IT1=1
      CALL KCOR
      ISEP=0
53    CALL FLASH
      CALL MOLES
      CALL EQR
      IF (ABS(SUMER).LE.1.E-5) GO TO 55
      IF (IT1.GE.100) GO TO 60
      IT1=IT1+1
      GO TO 53
55    F=0.
      DO 56 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 56
           F=F+Z1(I)*K(I)
56    CONTINUE
      IF (F.LE.1.) GO TO 70
58 CONTINUE
   GO TO 63
60 WRITE(1,110)ITE
   WRITE(2,110)ITE
   GO TO 70
63 WRITE(1,120)P,F
   WRITE(2,120)P,F
   GO TO 70
65 P=0.
70 PB=P
   RETURN
110 FORMAT(/1X,'K-VALUES DO NOT CONVERGE AFTER =',2X,I3,2X,'ITERATION'
  *)
120 FORMAT(/3X,'AT PRESSURE = ',2X,F8.2,2X,'PSIA',3X,'SUM OF ZXK = ',
  *2X,F8.6)
   END
```

```
      SUBROUTINE DATA1
C
C     PURPOSE : INTERPRET INPUT INFORMATION.
C
      COMMON/D1/CN(16)
      COMMON/D2/MW(16),MVOL(16)
      COMMON/D3/W(16),PC(16),TC(16)
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D5/X(16),Y(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D12/ISEP,NCOM,P1
      COMMON/D13/MWC7,SGC7
      COMMON/D20/INPUTW,GMWC7,SGGC7,GOR,
     *IOUT,FLSH,DIFF,OUTPUT,PSEP(5),TSEP(5)
      COMMON/D21/IPRINT
      REAL K,MWC7,MW,MVOL
      CHARACTER*1 IPRINT
      CHARACTER*9 CN
      CHARACTER*14 INFILE,FLSH,DIFF,OUTPUT
      IF (INPUTW.EQ.1) GO TO 30
      IF (INPUTW.EQ.2) GO TO 73
      GO TO 97
C     SEPARATOR OUTPUT COMPOSITION GIVEN - RECOMBINATION REQUIRED.
   30 IF (X(16).LT.1.E-25.AND.Y(16).LT.1.E-25) GO TO 50
      CALL ACEF
   50 SUM1=0.
      DO 55 I=1,16
          SUM1=SUM1+X(I)*MVOL(I)
   55 CONTINUE
      CUML=1./SUM1
      CUMG=GOR/379.4
      CUMGL=CUMG+CUML
C     STORES GLOBAL MOLE FRACTION IN Z1.
      DO 60 I=1,16
          Z1(I)=(X(I)*CUML+Y(I)*CUMG)/CUMGL
   60 CONTINUE
      DO 65 J=1,16
          IF (Z1(J).GT.0.) GO TO 70
   65 CONTINUE
   70 SUMZ=0.
      DO 72 I=J+1,16
          SUMZ=SUMZ+Z1(I)
   72 CONTINUE
      Z1(J)=1.-SUMZ
      IF (Z1(16).LT.1.E-25) GO TO 95
      GO TO 95
C     WELL STREAM COMPOSITION IS GIVEN.
   73 SUMZ=0.
      DO 80 I=1,16
          SUMZ=SUMZ+Z1(I)
```

```
 80 CONTINUE
    IF (Z1(16).LT.1.E-25) GO TO 95
    CALL ACEF
 95 P=PR
    T=TR
    GO TO 98
 97 WRITE(1,220)
 98 RETURN
220 FORMAT(/3X,'INPUT ERROR.')
    END
```

```
      SUBROUTINE DENSL
C
C     PURPOSE : CALCULATE LIQUID MOLAR VOLUME AND DENSITY,AND GAS
C               SPECIFIC GRAVITY.
C
C     INPUT PARAMETERS :
C       MVOL = COMPONENT MOLAR VOLUME (CU.FT/LB-MOLE)
C       MW   = MOLECULAR WEIGHT (LB/LB-MOLE)
C       P    = PRESSURE (PSIA)
C       T    = TEMPERATURE (DEG.F)
C       Z2   = COMPONENT GLOBAL MOLE FRACTION
C       ZL   = LIQUID COMPRESSIBILITY FACTOR
C     OUTPUT PARAMETERS :
C       DENL = LIQUID DENSITY (LB/CU.FT)
C       SGG  = GAS SPECIFIC GRAVITY (AIR=1)
C       VL   = LIQUID MOLAR VOLUME (CU.FT/LB-MOLE)
C
      REAL MVOL,MW,MWF
      COMMON/D2/MW(16),MVOL(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D7/ZL,ZV
      COMMON/D14/VL,DENL,SGG,MLG,MS,Z2(16)
      DATA R/10.731/
      T1=T+460.
      MWF=0.
      VSC=0.
      DO 10 I=1,16
           IF (Z2(I).LT.1.E-25) GO TO 10
           MWF=MWF+Z2(I)*MW(I)
           VSC=VSC+Z2(I)*MVOL(I)
   10 CONTINUE
      IF (MLG.EQ.2) GO TO 30
      VL=ZL*R*T1/P
      DENL=MWF/VL
      IF (MS.EQ.1) GO TO 20
      GO TO 40
C     CALCULATE LIQUID DENSITY AT STANDARD CONDITIONS.
   20 VL=(VL+VSC)/2.
      DENL=MWF/VL
      GO TO 40
   30 SGG=MWF/28.97
   40 RETURN
      END
```

```
      SUBROUTINE DOUT
C
C     PURPOSE : PRINT OUTPUT DATA ON PHASE COMPOSITION.
C
C     OUTPUT PARAMETERS :
C       CN   = COMPONENT NAME
C       K    = EQUILIBRIUM RATIO
C       NG   = GAS MOLE FRACTION (FLASH VAP.)
C       NGD  = GAS MOLE FRACTION (DIFFERENTIAL VAP.)
C       NL   = LIQUID MOLE FRACTION (FLASH VAP.)
C       NLD  = LIQUID MOLE FRACTION (DIFFERENTIAL VAP.)
C       P    = PRESSURE (PSIA)
C       SUMX = SUM OF COMPONENT LIQUID MOLE FRACTIONS (FLASH VAP.)
C       SUMXD = SUM OF COMPONENT LIQUID MOLE FRACTIONS (DIFFERENTIAL
C               VAP.)
C       SUMY = SUM OF COMPONENT GAS MOLE FRACTIONS (FLASH VAP.)
C       SUMYD = SUM OF COMPONENT GAS MOLE FRACTIONS (DIFFERENTIAL
C               VAP.)
C       SUMZ = SUM OF COMPONENT GLOBAL MOLE FRACTIONS (FLASH VAP.)
C       SUMZD = SUM OF COMPONENT GLOBAL MOLE FRACTIONS (DIFFERENTIAL
C               VAP.)
C       X    = COMPONENT LIQUID MOLE FRACTION (FLASH VAP.)
C       XD   = COMPONENT LIQUID MOLE FRACTION (DIFFERENTIAL VAP.)
C       Y    = COMPONENT GAS MOLE FRACTION (FLASH VAP.)
C       YD   = COMPONENT GAS MOLE FRACTION (DIFFERENTIAL VAP.)
C       Z    = COMPONENT GLOBAL MOLE FRACTION (FLASH VAP.)
C       Z3   = COMPONENT GLOBAL MOLE FRACTION (DIFFERENTIAL VAP.)
C       ZL   = LIQUID COMPRESSIBILITY/DEVIATION FACTOR
C       ZV   = GAS COMPRESSIBILITY/DEVIATION FACTOR
C     FLAG :
C       ISEP = INDICATES TYPE OF FLUID VAP. CALCULATIONS. ISEP=0
C              INDICATES FLASH VAP. AND ISEP=2 INDICATES
C              DIFFERENTIAL VAP. CALCULATIONS.
C
      COMMON/D1/CN(16)
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D5/X(16),Y(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D7/ZL,ZV
      COMMON/D10/NG,NL,SUMX,SUMY
      COMMON/D12/ISEP,NCOM,P1
      COMMON/D16/NGD,NLD,XD(16),YD(16),SUMXD,SUMYD
      CHARACTER*9 CN
      REAL K,NG,NL,NGD,NLD
      IF (ISEP.GT.1) GO TO 20
      WRITE(4,101)
      WRITE(4,100)
      WRITE(4,110)P1,T,NG,NL
      WRITE(4,125)
      DO 16 I=1,16
```

```
      IF (Z1(I).LT.1.E-25) GO TO 16
      WRITE(4,135)CN(I),Z1(I),K(I),X(I),Y(I)
16 CONTINUE
   WRITE(4,155)SUMZ,SUMX,SUMY
   WRITE(4,180)ZL,ZV
   GO TO 50
20 WRITE(3,101)
   WRITE(3,160)
   WRITE(3,110)P1,T,NGO,NLO
   WRITE(3,125)
   DO 45 I=1,16
      IF (Z3(I).LT.1.E-25) GO TO 45
      WRITE(3,135)CN(I),Z3(I),K(I),XD(I),YD(I)
45 CONTINUE
   WRITE(3,155)SUMZ,SUMXD,SUMYD
   WRITE(3,180)ZL,ZV
50 RETURN
101 FORMAT(/20X,26('*'),/20X,'*',1X,'BLACK OIL PVT ANALYSIS',1X,'*',
  *,/20X,26('*'))
100 FORMAT(/3X,'FLASH SEPARATION CALCULATIONS.',/3X,'----------------
  *----------')
110 FORMAT(/3X,'PRESSURE = ',2X,F6.1,2X,'PSIA',/3X,'TEMPERATURE = ',
  *2X,F6.1,2X,'DEG.F',/3X,'GAS MOLE FRACTION = ',2X,F6.4,/3X,
  *'LIQUID MOLE FRACTION = ',2X,F6.4)
125 FORMAT(/18X,'TOTAL',5X,'EQUILIBRIUM',5X,'LIQUID',8X,'GAS',/3X,
  *'COMPONENT',2X,'COMPOSITION',2X,'RATIO(CAL)',3X,'COMPOSITION',
  *2X,'COMPOSITION',/)
135 FORMAT(3X,A10,3X,F6.4,6X,F8.4,6X,F6.4,7X,F6.4)
155 FORMAT(16X,F6.4,20X,F6.4,7X,F6.4)
160 FORMAT(/3X,'DIFFERENTIAL VAPORIZATION CALCULATIONS.',/3X,'--------
  *----------------------------------')
180 FORMAT(3X,'Z-FACTOR',28X,F6.4,7X,F6.4)
   END
```

```
      SUBROUTINE DVAP
C
C     PURPOSE : CALCULATES LIQUID AND VAPOR MOLE FRACTIONS DUE TO
C               DIFFERENTIAL VAPORIZATION.
C
C     INPUT PARAMETERS :
C       K  = EQUILIBRIUM RATIO
C       Z3 = COMPONENT GLOBAL MOLE FRACTION
C     OUTPUT PARAMETERS :
C       NGD  = GAS MOLE FRACTION
C       NLD  = LIQUID MOLE FRACTION
C       SUMXD = SUM OF COMPONENT LIQUID MOLE FRACTIONS
C       SUMYD = SUM OF COMPONENT GAS MOLE FRACTIONS
C       SUMZD = SUM OF COMPONENT GLOBAL MOLE FRACTIONS
C       XD   = COMPONENT LIQUID MOLE FRACTION
C       YD   = COMPONENT GAS MOLE FRACTION
C
      REAL K,NGD,NLD
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D16/NGD,NLD,XD(16),YD(16),SUMXD,SUMYD
C     CALCULATE LIQUID AND VAPOR MOLE FRACTIONS USING NEWTON-RAPHSON
C     METHOD.
      IT1=1
      NLD=0.5
   10 F=0.
      FPRIME=0.
      DO 20 I=1,16
      IF (Z3(I).LT.1.E-25) GO TO 20
          F=F+Z3(I)*(NLD**(K(I)-1.))*(K(I)-1.)
          FPRIME=FPRIME+Z3(I)*(NLD**(K(I)-2.))*((K(I)-1.)**2)
   20 CONTINUE
      IF (ABS(F).LT.1.E-6) GO TO 30
      NLD=NLD-F/FPRIME
      IF (NLD.LE.0.) GO TO 40
      IT1=IT1+1
      IF (IT1.GT.100) GO TO 80
      GO TO 10
C     CALCULATE LIQUID MOLE FRACTION USING COMBINED BISECTION/SECANT/
C     INVERSE QUADRATIC INTERPOLATION METHOD.
   30 IF (NLD.GE.1.) GO TO 60
C     CALCULATES LIQUID AND VAPOR MOLE FRACTIONS OF EACH COMPONENT.
      SUMXD=0.
      SUMYD=0.
      SUMZ=0.
      DO 35 I=1,16
          IF (Z3(I).LT.1.E-25) GO TO 32
          XD(I)=Z3(I)*(NLD**(K(I)-1.))
          YD(I)=XD(I)*K(I)
          SUMXD=SUMXD+XD(I)
          SUMYD=SUMYD+YD(I)
```

```
      SUMZ=SUMZ+Z3(I)
      GO TO 35
32    XD(I)=0.
      YD(I)=0.
35 CONTINUE
   NGO=1.-NLO
   GO TO 90
40 NLO=0.
   NGO=1.
   SUMXD=0.
   SUMYD=0.
   DO 50 I=1,16
      XD(I)=0.
      YD(I)=Z3(I)
      SUMYD=SUMYD+YD(I)
50 CONTINUE
   SUMZ=SUMYD
   GO TO 90
60 NLO=1.
   NGO=0.
   SUMXD=0.
   SUMYD=0.
   DO 70 I=1,16
      XD(I)=Z3(I)
      YD(I)=0.
      SUMXD=SUMXD+XD(I)
70 CONTINUE
   SUMZ=SUMXD
   GO TO 90
80 WRITE(1,100)
90 RETURN
100 FORMAT(//3X,'NO CONVERGENCE IN SUBROUTINE DVAP.')
   END
```

```
      SUBROUTINE EQR
C
C     PURPOSE : CALCULATE EQUILIBRIUM RATIO OF EACH COMPONENT USING
C               THE PENG-ROBINSON EQUATION OF STATE.
C
C     INPUT PARAMETERS :
C       D  = BINARY INTERACTION FACTOR
C       P  = PRESSURE (PSIA)
C       T  = TEMPERATURE (DEG.F)
C       TC = CRITICAL TEMPERATURE (DEG.F)
C       W  = ACENTRIC FACTOR
C       X  = COMPONENT LIQUID MOLE FRACTION
C       Y  = COMPONENT GAS MOLE FRACTION
C       ZL = LIQUID COMPRESSIBILITY/DEVIATION FACTOR
C       ZV = GAS COMPRESSIBILITY/DEVIATION FACTOR
C     OUTPUT PARAMETERS :
C       K  = EQUILIBRIUM RATIO
C     OTHER PARAMETERS :
C       FRAT = FUGACITY RATIO (IN ACC. SUCCESSIVE SUBSTITUTION)
C       FUGR = FUGACITY RATIO (IN SUCCESSIVE SUBSTIUTTION)
C       LAMDA = ACCELERATION FACTOR
C       OLDFR = PREVIOUS FUGACITY RATIO
C     FLAG :
C       IKV  = 2 INDICATES EQUILIBRIUM RATIOS ARE CALCULATED BY
C              USING THE P-R EQUATION OF STATE
C       METH = METHOD USED IN EQUILIBRIUM RATIO ESTIMATION.
C              METH=1 INDICATES USE OF SUCCESSIVE SUBSTITUTION AND
C              METH>1 INDICATES USE OF ACCELERATED SUCCESSIVE
C              SUBSTITUTION
C
      REAL K,LAMDA,MVOL,MW,NG,NL
      COMMON/D3/W(16),PC(16),TC(16)
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D5/X(16),Y(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D7/ZL,ZV
      COMMON/D9/D(16,16),IBIN,TB(16),IPB
      COMMON/D15/IKV,METH
      DIMENSION A(16),B(16),TC1(16),XA(16),YA(16),FRAT(16),OLDFR(16),
     *PK(16)
      DATA R/10.731/
      DATA ERROR/1.E-5/
      T1=T+460.
      DO 20 I=1,16
         IF (Z1(I).LT.1.E-25) GO TO 10
         TC1(I)=TC(I)+460.
         TRED=T1/TC1(I)
         A1=.37464+1.54226*W(I)-.26992*W(I)**2
         A2=1.+A1*(1.-SQRT(TRED))
         A3=.45724*(R**2)*(TC1(I)**2)/PC(I)
```

```
            A(I)=A3*(A2**2)
            B(I)=.0778*R*TC1(I)/PC(I)
            GO TO 20
   10       A(I)=0.
            B(I)=0.
   20 CONTINUE
C     CALCULATE Z-FACTOR OF LIQUID PHASE.
      ASL=0.
      BSL=0.
      DO 40 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 35
           BSL=BSL+X(I)*B(I)
           XL=0.
           DO 30 J=1,16
           IF (Z1(J).LT.1.E-25) GO TO 30
           AIJ=(1.-D(I,J))*(SQRT(A(I)*A(J)))
           ASL=ASL+X(I)*X(J)*AIJ
           XL=XL+X(J)*AIJ
   30      CONTINUE
           XA(I)=XL
           GO TO 40
   35      XA(I)=0.
   40 CONTINUE
      AL=ASL*P/((R*T1)**2)
C     INPUT PARAMETERS :
      BL=BSL*P/(R*T1)
      CALL QROOT(AL,BL,ZL,1)
C     CALCULATE Z-FACTOR OF VAPOR PHASE.
      ASV=0.
      BSV=0.
      DO 60 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 55
           BSV=BSV+Y(I)*B(I)
           YV=0.
           DO 50 J=1,16
           IF (Z1(J).LT.1.E-25) GO TO 50
           AIJ=(1.-D(I,J))*SQRT(A(I)*A(J))
           ASV=ASV+Y(I)*Y(J)*AIJ
           YV=YV+Y(J)*AIJ
   50      CONTINUE
           YA(I)=YV
           GO TO 60
   55      YA(I)=0.
   60 CONTINUE
      AV=ASV*P/(R*T1)**2
      BV=BSV*P/(R*T1)
      CALL QROOT(AV,BV,ZV,2)
      IF ((ASL.LT.1.E-25).OR.(ASV.LT.1.E-25)) GO TO 61
      GO TO 59
   61 SUMER=0.
```

```
      GO TO 95
C     CALCULATE COMPONENT FUGACITY COEFFICIENTS AND K-VALUES.
   59 CONS1=(ZL-1.)/BSL-(ZU-1.)/BSU
      CONS2=ALOG((ZU-BU)/(ZL-BL))
      CONSL=(AL/(SQRT(8.)*BL))*ALOG((ZL+(SQRT(2.)+1.)*BL)/(ZL-(SQRT(2.)
     *     -1.)*BL))
      CONSU=(AU/(SQRT(8.)*BU))*ALOG((ZU+(SQRT(2.)+1.)*BU)/(ZU-(SQRT(2.)
     *     -1.)*BU))

      IF (METH.GT.1) GO TO 81

C     ESTIMATE K-VALUES USING SUCCESSIVE SUBSTITUTION METHOD.
      SUMER=0
      DO 80 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 65
           FUGR=ALOG(X(I)/Y(I))+B(I)*CONS1+CONS2-CONSL*(2.*XA(I)/ASL-
     *          B(I)/BSL)+CONSU*(2.*YA(I)/ASU-B(I)/BSU)
           PK(I)=K(I)
           K(I)=PK(I)*EXP(FUGR)
           DIF=K(I)-PK(I)
           PROD=K(I)*PK(I)
           IF (PROD.LT.1.E-20) PROD=1.E-20
           SUMER=SUMER+DIF*DIF/PROD
           GO TO 80
   65      K(I)=0.
   80 CONTINUE
      GO TO 95
C     ESTIMATE K-VALUES USING ACCELERATED SUCCESSIVE SUBSTITUTION
C     METHOD.
   81 SUMFR1=0.
      SUMFR2=0.
      SUMER=0.
      RMAX=0.
      IF (IKV.EQ.2) GO TO 75
      DO 72 I=1,16
           OLDFR(I)=1.0
   72 CONTINUE
   75 DO 82 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 82
           FRAT(I)=ALOG(X(I)/Y(I))+B(I)*CONS1+CONS2-CONSL*(2.*XA(I)/ASL
     *          -B(I)/BSL)+CONSU*(2.*YA(I)/ASU-B(I)/BSU)
           SUMFR1=SUMFR1+OLDFR(I)**2
           SUMFR2=SUMFR2+OLDFR(I)*FRAT(I)
           RMAX=AMAX1(RMAX,ABS(FRAT(I)))
           OLDFR(I)=FRAT(I)
   82 CONTINUE
      IF (IKV.EQ.1) GO TO 83
      DIF=ABS(SUMFR1-SUMFR2)
      IF (DIF.GT.(ERROR**2*SUMFR2)) GO TO 84
   83 LAMDA=1.0
```

```
      GO TO 86
   84 LAMDA=SUMFR1/DIF*LAMDA
      RLIM=LAMDA*RMAX
      IF (RLIM.GT.6.) LAMDA=6./RMAX
   86 DO 88 I=1,16
            IF (Z1(I).LT.1.E-25) GO TO 87
            PK(I)=K(I)
            K(I)=PK(I)*EXP(LAMDA*FRAT(I))
            DIF=K(I)-PK(I)
            PROD=K(I)*PK(I)
            IF (PROD.LT.1.E-20) PROD=1.E-20
            SUMER=SUMER+DIF*DIF/PROD
            GO TO 88
   87       K(I)=0.
   88 CONTINUE
   95 IKV=2
      RETURN
      END
```

```
      SUBROUTINE FLASH
C
C     PURPOSE : CALCULATE PHASE MOLE FRACTIONS DUE TO FLASH
C               VAPORIZATION.
C
C       K  = EQUILIBRIUM RATIO
C       Z1 = COMPONENT GLOBAL MOLE FRACTION
C     OUTPUT PARAMETERS :
C       NG = GAS MOLE FRACTION
C       NL = LIQUID MOLE FRACTION
C
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D10/NG,NL,SUMX,SUMY
      COMMON/D15/IKV,METH
      EXTERNAL FX
      REAL K,NG,NL
C     CALCULATE PHASE MOLE FRACTIONS USING COMBINED BISECTION/SECANT/
C     INVERSE QUADRATIC INTERPOLATION METHOD.
      A=1.E-10
      B=1.0
      TOL=1.E-10
      NG=ZERODIN(A,B,FX,TOL)
      NL=1.-NG
      RETURN
      END
```

```
      REAL FUNCTION FX(X)
C
C     PURPOSE : CALCULATE FUNCTIONS F(X) AND F1(X) USED IN FLASH
C               AND DIFFERENTIAL VAPORIZATION CALCULATIONS,RESPECTIVELY.
C
C     INPUT PARAMETERS :
C       K  = EQUILIBRIUM RATIO
C       Z1 = COMPONENT GLOBAL MOLE FRACTION
C     OUTPUT PARAMETER :
C       FX = FUNCTION USED IN FLASH VAPORIZATION
C
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      REAL K
      DOUBLE PRECISION DIFF
      F=0.0
      DO 10 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 10
           DIFF=K(I)-1.
           F=F+Z1(I)*DIFF/(1.+X*DIFF)
   10 CONTINUE
      FX=F
      RETURN
      END
```

```
      REAL FUNCTION ZEROIN(AX,BX,FX,TOL)
C
C     PURPOSE : COMPUTE A ROOT OF FUNCTION FX(X) IN THE INTERVAL
C               AX,BX
C
C     INPUT PARAMETERS:
C       AX  = LEFT ENDPOINT OF INITIAL INTERVAL
C       BX  = RIGHT ENDPOINT OF INITIAL INTERVAL
C       FX  = FUNCTION SUBPROGRAM WHICH EVALUATES FX(X) FOR ANY
C             X IN THE INTERVAL AX,BX
C       TOL = DESIRED TOLERANCE (1.E-10)
C
C     OUTPUT PARAMETER:
C       ZEROIN = COMPUTED ROOT OF FUNCTION FX(X)
C
C     COMPUTE EPS,THE RELATIVE MACHINE PRECISION.
C
      EPS=1.0
   10 EPS=EPS/2.0
      TOL1=1.0+EPS
      IF (TOL1.GT.1.0) GO TO 10
C     INITIALIZATION.
      A=AX
      B=BX
      FA=FX(A)
      FB=FX(B)
C     BEGIN STEP
   20 C=A
      FC=FA
      D=B-A
      E=D
   30 IF (ABS(FC).GE.ABS(FB)) GO TO 40
      A=B
      B=C
      C=A
      FA=FB
      FB=FC
      FC=FA

C     CONVERGENCE TEST.
   40 TOL1=2.0*EPS*ABS(B)+0.5*TOL
      XM=0.5*(C-B)
      IF (ABS(XM).LE.TOL1) GO TO 90
      IF (FB.EQ.0.0) GO TO 90
C     IS BISECTION NECESSARY.
      IF (ABS(E).LT.TOL1) GO TO 70
      IF (ABS(FA).LE.ABS(FB)) GO TO 70
C     IS QUADRATIC INTERPOLATION POSSIBLE.
      IF (A.NE.C) GO TO 50
C     LINEAR INTERPOLATION (SECANT METHOD).
```

```
      S=FB/FA
      P=2.0*XM*S
      Q=1.0-S
      GO TO 60
C     INVERSE QUADRATIC FUNCTION.
   50 Q=FA/FC
      R=FB/FC
      S=FB/FA
      P=S*(2.0*XM*(Q-R)-(B-A)*(R-1.0))
      Q=(Q-1.0)*(R-1.0)*(S-1.0)
C     ADJUST SIGNS.
   60 IF (P.GT.0.0) Q=-Q
      P=ABS(P)
C     IS INTERPOLATION ACCEPTABLE.
      IF ((2.0*P).GE.(3.0*XM*Q-ABS(TOL1*Q))) GO TO 70
      IF (P.GE.ABS(0.5*E*Q)) GO TO 70
      E=D
      D=P/Q
      GO TO 80
C     BISECTION.
   70 D=XM
      E=D
C     COMPLETE STEP.
   80 A=B
      FA=FB
      IF (ABS(D).GT.TOL1) B=B+D
      IF (ABS(D).LE.TOL1) B=B+SIGN(TOL1,XM)
      FB=FX(B)
      IF ((FB*(FC/ABS(FC))).GT.0.0) GO TO 20
      GO TO 30
C     DONE
   90 ZEROIN=B
      RETURN
      END
```

```
      SUBROUTINE KCOR
C
C     PURPOSE : ESTIMATE INITIAL SET OF EQUILIBRIUM RATIOS USING
C               CORRELATION.
C
C     INPUT PARAMETERS :
C       P   = PRESSURE (PSIA)
C       PC  = CRITICAL PRESSURE (PSIA)
C       T   = TEMPERATURE (DEG.F)
C       TC  = CRITICAL TEMPERATURE (DEG.F)
C       W   = ACENTRIC FACTOR
C     OUTPUT PARAMETERS :
C       K   = EQUILIBRIUM RATIO
C     FLAG :
C       IKV = 1 INDICATES EQUILIBRIUM RATIOS ARE ESTIMATED FROM
C       CORRELATION.
C
      COMMON/D3/W(16),PC(16),TC(16)
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D15/IKV,METH
      DIMENSION TC1(16)
      REAL K
      IKV=1
      T1=T+460.
      DO 20 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 10
           TC1(I)=TC(I)+460.
           K(I)=EXP(5.37*(1.+W(I))*(1.-TC1(I)/T1))/(P/PC(I))
           GO TO 20
   10      K(I)=0.
           TC1(I)=0.
   20 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MOLES
C
C     PURPOSE : CALCULATE COMPONENT PHASE MOLE FRACTIONS.
C
C     INPUT PARAMETERS :
C       K    = EQUILIBRIUM RATIO
C       NG   = GAS MOLE FRACTION
C       NL   = LIQUID MOLE FRACTION
C       Z1   = COMPONENT GLOBAL MOLE FRACTION
C     OUTPUT PARAMETERS :
C       SUMX = SUM OF COMPONENT LIQUID MOLE FRACTIONS
C       SUMY = SUM OF COMPONENT GAS MOLE FRACTIONS
C       SUMZ = SUM OF COMPONENT GLOBAL MOLE FRACTIONS
C       X    = COMPONENT LIQUID MOLE FRACTION
C       Y    = COMPONENT GAS MOLE FRACTION
C
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D5/X(16),Y(16)
      COMMON/D10/NG,NL,SUMX,SUMY
      REAL K,NG,NL
C     CALCULATE COMPONENT MOLE FRACTIONS.
      SUMX=0.
      SUMY=0.
      SUMZ=0.
      IF ((1.-NL).LT.1.E-6) GO TO 60
      IF (NL.LT.1.E-6) GO TO 70
      NG=1.-NL
      IF (NL.GT.NG) GO TO 55
      DO 50 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 40
           X(I)=Z1(I)/(K(I)+NL*(1.-K(I)))
           Y(I)=K(I)*X(I)
           SUMX=SUMX+X(I)
           SUMY=SUMY+Y(I)
           SUMZ=SUMZ+Z1(I)
           GO TO 50
   40      X(I)=0.
           Y(I)=0.
   50 CONTINUE
      GO TO 90
   55 DO 58 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 56
           X(I)=Z1(I)/(1.+NG*(K(I)-1.))
           Y(I)=K(I)*X(I)
           SUMX=SUMX+X(I)
           SUMY=SUMY+Y(I)
           SUMZ=SUMZ+Z1(I)
           GO TO 58
   56      X(I)=0.
           Y(I)=0.
```

```
58 CONTINUE
   GO TO 90
60 NL=1.
   NG=0.
   DO 65 I=1,16
        X(I)=Z1(I)
        Y(I)=0.
        SUMX=SUMX+X(I)
65 CONTINUE
   SUMZ=SUMX
   GO TO 90
70 NL=0.
   NG=1.
   DO 75 I=1,16
        X(I)=0.
        Y(I)=Z1(I)
        SUMY=SUMY+Y(I)
75 CONTINUE
   SUMZ=SUMY
90 RETURN
   END
```

```
      SUBROUTINE QROOT(A,B,ROOT,L)
C
C     PURPOSE : CALCULATE THE REAL ROOTS OF THE PENG-ROBINSON CUBIC
C               EQUATION OF STATE IN Z-FACTOR.
C
C     INPUT PARAMETERS :
C       A,B = PARAMETERS OBTAINED FROM THE PENG-ROBINSON
C             EQUATION OF STATE.
C     OUTPUT PARAMETERS :
C       ROOT = LIQUID OR GAS COMPRESSIBILITY/DEVIATION FACTOR
C     FLAG :
C       L = 1 INDICATES LIQUID PHASE.
C       L = 2 INDICATES GAS PHASE.
C
      C1=B*(B*B+B-A)
      C2=A-B*(B*3.+2.)
      C3=B-1.
      B1=(3.*C2-C3*C3)/3.
      B0=(2.*(C3**3)-9.*C2*C3+27.*C1)/27.
      DET=(B1/3.)**3+(B0/2.)**2
      IF (DET.LT.0.) GO TO 10
      IF (DET.LT.1.E-20) GO TO 20
      L1=1
      GO TO 20
   10 IF (B1.GT.0.) GO TO 95
      PHI=ACOS((-B0/2.)*(-3./B1)**1.5)
      PI=2.*ASIN(1.0)
      B2=2.*SQRT(-B1/3.)
      Y1=B2*COS(PHI/3.)-C3/3.
      Y2=B2*COS(PHI/3.+2.*PI/3.)-C3/3.
      Y3=B2*COS(PHI/3.+4.*PI/3.)-C3/3.
      IF (L.EQ.1) GO TO 15
      ROOT=AMAX1(Y1,Y2,Y3)
      GO TO 90
   15 IF (Y1.LE.0.) Y1=1.E6
      IF (Y2.LE.0.) Y2=1.E6
      IF (Y3.LE.0.) Y3=1.E6
      ROOT=AMIN1(Y1,Y2,Y3)
      IF (ROOT.GT.1.E5) GO TO 95
      GO TO 90
   20 DET1=SQRT(DET)
      F1=-B0/2.+DET1
      F2=-B0/2.-DET1
      IF (F1.LT.0.0.AND.F2.LT.0.0) GO TO 30
      IF (F1.LT.0.0.AND.F2.GT.0.0) GO TO 40
      IF (F1.GT.0.0.AND.F2.LT.0.0) GO TO 50
      Y1=F1**(1./3.)+F2**(1./3.)-C3/3.
      GO TO 60
   30 F1=-F1
      F2=-F2
```

```
      Y1=-(F1**(1./3.)+F2**(1./3.))-C3/3.
      GO TO 60
   40 F1=-F1
      Y1=-(F1**(1./3.))+F2**(1./3.)-C3/3.
      GO TO 60
   50 F2=-F2
      Y1=F1**(1./3.)-(F2**(1./3.))-C3/3.
   60 IF (L1.EQ.1) GO TO 70
      F4=-B0/2.
      IF (F4.LT.0.) THEN
        F4=-F4
        Y2=-(F4**(1./3.))-C3/3.
      ELSE
        Y2=F4**(1./3.)-C3/3.
      ENDIF
      IF (L.EQ.1) GO TO 65
      ROOT=AMAX1(Y1,Y2)
      GO TO 90
   65 IF (Y1.LE.0.0.AND.Y2.LE.0.) GO TO 95
      IF (Y1.LE.0.) THEN
        ROOT=Y2
      ELSE
        ROOT=Y1
      ENDIF
      GO TO 90
   70 ROOT=Y1
      GO TO 90
   95 WRITE(1,100)
      WRITE(2,100)
   90 L1=2
      RETURN
  100 FORMAT(/3X,'NO ROOTS AVAILABLE IN SUB.QROOT.')
      END
```

```
      SUBROUTINE VISCG(PRES,T2,GG,Z,VGAS)
C
C     PURPOSE : CALCULATE GAS VISCOSITY USING LEE-EAKIN CORRELATION.
C
C     INPUT PARAMETERS :
C       GG   = GAS SPECIFIC GRAVITY (AIR=1)
C       PRES = PRESSURE (PSIA)
C       T2   = TEMPERATURE (DEG.F)
C       Z    = GAS COMPRESSIBILITY/DEVIATION FACTOR
C     OUTPUT PARAMETERS :
C       VGAS = GAS VISCOSITY (CP)
C
      REAL K
      IF (Z.LE.0.) GO TO 10
      TEMP=T2+460.
      K=(9.4+.58*GG)*(TEMP**1.5)/(209.+551.*GG+TEMP)
      X=3.5+986./TEMP+.2897*GG
      G=2.4-.2*X
      DENS=.043264*GG*PRES/(Z*TEMP)
      VGAS=K*EXP(X*DENS**G)/10000.
      GO TO 20
   10 VGAS=0.
   20 RETURN
      END
```

```
      SUBROUTINE VISCL(DEN,TEMP,RS,VISL,M)
C
C     PURPOSE : CALCULATE LIQUID VISCOSITY USING BEGGS-ROBINSON
C               CORRELATION.
C
C     INPUT PARAMETERS :
C       DEN  = LIQUID DENSITY AT STANDARD CONDITIONS (LB/CU.FT)
C       RS   = SOLUTION GAS-OIL RATIO (SCF/STB)
C       TEMP = TEMPERATURE (DEG.F)
C       M    = NO. OF PRESSURE STAGES
C     OUTPUT PARAMETERS :
C       VISL = VISCOSITY OF LIQUID (CP)
C
      DIMENSION RS(M),VISL(M)
      DOAPI=141.5*62.4/DEN-131.5
      R1=3.0324-0.02023*DOAPI
      R2=10.**R1
      R3=R2*(TEMP**(-1.163))
      VISO=(10.**R3)-1.
      DO 10 I=1,M
         R4=10.715*((RS(I)+100.)**(-0.515))
         R5=5.44*((RS(I)+150.)**(-0.338))
         VISL(I)=R4*(VISO**R5)
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PHASEB
C
C     PURPOSE : IDENTIFY TYPE OF FLUID SYSTEM USING SUMMATION OF
C               Z*K AND Z/K.
C
C     INPUT PARAMETERS :
C       K  = EQUILIBRIUM RATIO
C       P  = PRESSURE (PSIA)
C       Z1 = COMPONENT GLOBAL MOLE FRACTION
C     OUTPUT PARAMETERS :
C       ID = TYPE OF FLUID SYSTEM; ID=1 INDICATES BLACK/VOLATILE
C            OIL SYSTEM, AND ID=3 INDICATES RETROGRADE CONDENSATE
C            SYSTEM. ID=2 INDICATES TWO-PHASE FLUID BEHAVIOR.
C
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D11/ID,MM
      REAL K
C     CALCULATE K-VALUES AT GIVEN PRESSURE $ TEMPERATURE.
      ID=4
      P=PR
   10 ITE=1
      CALL KCOR
   14 CALL FLASH
      CALL MOLES
      CALL EQR
      IF (ABS(SUMER).LE.1.E-5) GO TO 20
      IF (ITE.GE.100) GO TO 16
      ITE=ITE+1
      GO TO 14
   16 WRITE(1,190)
      WRITE(2,190)
      ID=0
      GO TO 80
C     CHECK FOR PHASE BEHAVIOR OF FLUID.
   20 SUMKZ1=0.
      SUMKZ2=0.
      DO 30 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 30
           SUMKZ1=SUMKZ1+Z1(I)*K(I)
           SUMKZ2=SUMKZ2+Z1(I)/K(I)
   30 CONTINUE
      IF (ABS(SUMKZ1-1.0).LT.1.E-4) GO TO 40
      IF (ABS(SUMKZ2-1.0).LT.1.E-4) GO TO 45
      IF ((SUMKZ1.GT.1.0).AND.(SUMKZ2.GT.1.0)) GO TO 50
      IF ((SUMKZ1.LT.1.0).AND.(SUMKZ2.LT.1.0)) GO TO 55
      IF (SUMKZ1.LT.1.0) GO TO 60
      IF (ID.EQ.2) GO TO 47
      GO TO 47
   40 IF (ID.EQ.2) GO TO 65
```

```
      GO TO 65
   45 IF (ID.EQ.2) GO TO 47
   47 ID=3
      GO TO 70
   50 IF (ID.EQ.2) GO TO 70
      ID=2
      GO TO 70
   55 CONTINUE
      ID=0
      GO TO 70
   60 IF (ID.EQ.2) GO TO 65
   65 ID=1
   70 CONTINUE
      IF (ID.NE.2) GO TO 80
      P=P+100.
      GO TO 10
   80 RETURN
  100 FORMAT(/1X,'NO CONVERGENCE IN SUB. PHASEB AFTER 100 ITERATIONS.')
      END
```

```
      SUBROUTINE INPUT
C
C     PURPOSE : READS INPUT DATA
C
      COMMON/D1/CN(16)
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D5/X(16),Y(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D8/PB,PBEXP
      COMMON/D9/D(16,16),IBIN,TB(16),IPB
      COMMON/D13/MWC7,SGC7
      COMMON/D15/IKV,METH
      COMMON/D20/INPUTW,GMWC7,SGGC7,GOR,
     *IOUT,FLSH,DIFF,OUTPUT,PSEP(5),TSEP(5)
      COMMON/D21/IPRINT
      COMMON/D22/NS
      CHARACTER*14 INFILE,FLSH,DIFF,OUTPUT
      CHARACTER*9 CN
      CHARACTER*1 RESP,IPRINT
      REAL MWC7
      DO 1 I=1,16
        X(I)=1.
        Y(I)=1.
        Z1(I)=1.
    1 CONTINUE
      WRITE(*,*)'                ***BLACK OIL PVT ANALYSIS***'
    2 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'            ****************************************'
      WRITE(*,*)'            *  (1) INPUT DATA FOR CALCULATION    *'
      WRITE(*,*)'            *                OR                  *'
      WRITE(*,*)'            *  (2) RETRIEVE DATA INPUT FILE      *'
      WRITE(*,*)'            ****************************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,*)INPUT
      IF (INPUT.LT.1.OR.INPUT.GT.2) GO TO 2
      IF (INPUT.EQ.2) THEN
      WRITE(*,'(A\)')' NAME OF INPUT FILE TO BE RETRIEVED ? -->'
      READ(*,'(A)')INFILE
      OPEN(9,FILE=INFILE,STATUS='OLD')
      READ(9,*)INPUTW,(X(I),Y(I),Z1(I),I=1,16),MWC7,SGC7,GMWC7,SGGC7,
     *GOR,PR,TR,PBEXP,METH,IBIN,IOUT
      READ(9,'(4A)')FLSH,DIFF,OUTPUT,IPRINT
      READ(9,*)NS
      IF (NS.LT.0.OR.NS.GT.5) GO TO 35
      IF (NS.GT.0) THEN
```

```
      READ(9,*)(PSEP(I),TSEP(I),I=1,NS)
      ENDIF
      IF (INPUTW.EQ.1.OR.INPUTW.EQ.2) GO TO 12
   35 WRITE(*,'(A)') BAD INPUT FILE'
      GO TO 2
      ENDIF
    3 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'                    ************************'
      WRITE(*,*)'                    *     SAMPLE TYPE      *'
      WRITE(*,*)'                    ************************'
      WRITE(*,*)'                    *  (1) RECOMBINATION   *'
      WRITE(*,*)'                    *        OR            *'
      WRITE(*,*)'                    *  (2) WELL-STREAM     *'
      WRITE(*,*)'                    ************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,*)INPUTW
      IF (INPUTW.LT.1.OR.INPUTW.GT.2) GO TO 3
      IF (INPUTW.EQ.2) GO TO 5
      WRITE(*,'(A)')' INPUT MOLE FRACTIONS FOR THE FOLLOWING COMPONENTS'
      WRITE(*,'(A)')' (LIQUID FRACTION,VAPOR FRACTION)'
      DO 4 I=1,16
       WRITE(*,'(A,A9,A\)')' ',CN(I),'  -->'
       READ(*,*)X(I),Y(I)
    4 CONTINUE
      GO TO 7
    5 WRITE(*,'(A)')' INPUT MOLE FRACTIONS FOR THE FOLLOWING COMPONENTS'
      DO 6 I=1,16
       WRITE(*,'(A,A9,A\)')' ',CN(I),'  -->'
       READ(*,*)Z1(I)
    6 CONTINUE
    7 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A)')' ENTER THE FOLLOWING PARAMETERS'
      WRITE(*,*)
      WRITE(*,'(A\)')' MOLECULAR WEIGHT OF THE LIQUID PHASE HEAVY+ -->'
      READ(*,*)MWC7
      WRITE(*,'(A\)')' SPECIFIC GRAVITY OF THE LIQUID PHASE HEAVY+ -->'
      READ(*,*)SGC7
      WRITE(*,'(A)')' MOLECULAR WEIGHT OF THE VAPOR PHASE HEAVY+'
      WRITE(*,'(A)')' IF NOT AVAILABLE, TYPE 0.'
      WRITE(*,'(A\)')' -->'
      READ(*,*)GMWC7
      WRITE(*,'(A)')' SPECIFIC GRAVITY OF THE VAPOR PHASE HEAVY+'
      WRITE(*,'(A)')' IF NOT AVAILABLE, TYPE 0.'
```

```
      WRITE(*,'(A\)')' -->'
      READ(*,*)SGGC7
      WRITE(*,*)
      WRITE(*,'(A)')' SYSTEM GAS-OIL RATIO (SCF/STB)'
      WRITE(*,'(A)')' FOR WELL-STREAM SAMPLE, TYPE 0.'
      WRITE(*,'(A\)')' -->'
      READ(*,*)GOR
      WRITE(*,'(A\)')' SYSTEM PRESSURE (PSIA) -->'
      READ(*,*)PR
      WRITE(*,'(A\)')' SYSTEM TEMPERATURE (DEG.F) -->'
      READ(*,*)TR
      WRITE(*,'(A)')' EXPERIMENTAL BUBBLE POINT (PSIA)'
      WRITE(*,'(A)')' IF NOT AVAILABLE, TYPE 0.'
      WRITE(*,'(A\)')' -->'
      READ(*,*)PBEXP
   30 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'            **********************************'
      WRITE(*,*)'            *   DO YOU WANT MULTI-STAGE      *'
      WRITE(*,*)'            *   SEPARATION CALCULATIONS ?    *'
      WRITE(*,*)'            **********************************'
      WRITE(*,*)'            *   (0) NO                       *'
      WRITE(*,*)'            *   (1) YES, 1 STAGE             *'
      WRITE(*,*)'            *   (2) YES, 2 STAGES            *'
      WRITE(*,*)'            *   (3) YES, 3 STAGES            *'
      WRITE(*,*)'            *   (4) YES, 4 STAGES            *'
      WRITE(*,*)'            *   (5) YES, 5 STAGES            *'
      WRITE(*,*)'            **********************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,*)NS
      IF(NS.LT.0.OR.NS.GT.5.) GO TO 30
      IF(NS.GT.0) THEN
      WRITE(*,*)
      WRITE(*,*)' ENTER SEPARATOR PRESSURE (PSIA),TEMPERATURE (DEG.F)'
      WRITE(*,*)
      DO 31 I=1,NS
       WRITE(*,'(A,I1,A\)')' STAGE ',I,' -->'
       READ(*,*)PSEP(I),TSEP(I)
   31 CONTINUE
      ENDIF
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') GO TO 24
    8 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'      **************************************************'
      WRITE(*,*)'      *    EQUILIBRIUM RATIO ESTIMATION                *'
```

```
      WRITE(*,*)'      ************************************************'
      WRITE(*,*)'      *    (1) SUCCESSIVE SUBSTITUTION               *'
      WRITE(*,*)'      *                  OR                          *'
      WRITE(*,*)'      *    (2) ACCELERATED SUCCESSIVE SUBSTITUTION   *'
      WRITE(*,*)'      ************************************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,*)METH
      IF (METH.LT.1.OR.METH.GT.2) GO TO 8
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') GO TO 24
    9 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'          ****************************************'
      WRITE(*,*)'          *   ESTIMATION OF HC-N2 AND HC-CO2     *'
      WRITE(*,*)'          *   BINARY INTERACTION PARAMETERS      *'
      WRITE(*,*)'          ****************************************'
      WRITE(*,*)'          *   (1) GRABOWSKI-DAUBERT CORRELATION  *'
      WRITE(*,*)'          *                 OR                   *'
      WRITE(*,*)'          *   (2) LAVAL CORRELATION              *'
      WRITE(*,*)'          ****************************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,*)IBIN
      IF (IBIN.LT.1.OR.IBIN.GT.2) GO TO 9
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') GO TO 24
   10 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'          ****************************************'
      WRITE(*,*)'          *   DO YOU WANT PHASE COMPOSITION FILES ?  *'
      WRITE(*,*)'          ****************************************'
      WRITE(*,*)'          *              (Y) YES                   *'
      WRITE(*,*)'          *                                        *'
      WRITE(*,*)'          *              (N) NO                    *'
      WRITE(*,*)'          ****************************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,'(A)')IPRINT
      IF (IPRINT.NE.'Y'.AND.IPRINT.NE.'N') THEN
      IF (IPRINT.NE.'y'.AND.IPRINT.NE.'n') GO TO 10
      ENDIF
      IF (IPRINT.EQ.'Y'.OR.IPRINT.EQ.'y') THEN
      WRITE(*,*)
```

```
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'     ***INPUT FILE NAME (USING PC-DOS STANDARD)***'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' NAME OF FILE FOR FLASH PHASE COMPOSITIONS -->'
      READ(*,'(A)')FLSH
      WRITE(*,'(A\)')' NAME OF FILE FOR DIFFERENTIAL PHASE COMPOSITIONS
     *-->'
      READ(*,'(A)')DIFF
      ELSE
      FLSH='NO FILE'
      DIFF='NO FILE'
      ENDIF
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') GO TO 24
   11 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'          ************************'
      WRITE(*,*)'          *       OUTPUT         *'
      WRITE(*,*)'          ************************'
      WRITE(*,*)'          *   (1) TO PRINTER     *'
      WRITE(*,*)'          *         OR           *'
      WRITE(*,*)'          *   (2) TO FILE        *'
      WRITE(*,*)'          ************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,*)IOUT
      IF (IOUT.LT.1.OR.IOUT.GT.2) GO TO 11
      IF (IOUT.EQ.2) THEN
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'     ***INPUT FILE NAME (USING PC-DOS STANDARD)***'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' NAME OF FILE FOR OUTPUT -->'
      READ(*,'(A)')OUTPUT
      ELSE
      OUTPUT='PRN'
      ENDIF
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') GO TO 24
   12 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A)')' ***SUMMARY OF COMPONENT MOLE FRACTION***'
      WRITE(*,*)
      IF (INPUTW.EQ.2) GO TO 14
```

```
      WRITE(*,'(A)')'     COMPONENT     LIQUID MOLE   VAPOR MOLE'
      WRITE(*,'(A)')'                    FRACTION      FRACTION'
      DO 13 I=1,16
        WRITE(*,'(A,I2,2X,A9,6X,F8.6,6X,F8.6)')' ',I,CN(I),X(I),Y(I)
   13 CONTINUE
      WRITE(*,*)
      WRITE(*,'(A\)')' DO YOU WANT TO CHANGE ANY COMPONENT MOLE FRACTION
     * (Y OR N) ? -->'
      READ(*,'(A)')RESP
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') THEN
      WRITE(*,'(A\)')' ENTER LINE NUMBER OF COMPONENT TO BE CHANGED -->'
      READ(*,*)INT
      WRITE(*,'(A)')' ENTER (LIQUID FRACTION, VAPOR FRACTION)'
      WRITE(*,'(A,A,A\)')' ',CN(INT),'  -->'
      READ(*,*)X(INT),Y(INT)
      GO TO 12
      ELSE
      GO TO 16
      ENDIF
   14 WRITE(*,'(A)')'     COMPONENT    MOLE FRACTION'
      DO 15 I=1,16
        WRITE(*,'(A,I2,2X,A9,6X,F8.6)')' ',I,CN(I),Z1(I)
   15 CONTINUE
      WRITE(*,*)
      WRITE(*,'(A\)')' DO YOU WANT TO CHANGE ANY COMPONENT MOLE FRACTION
     * (Y OR N) ? -->'
      READ(*,'(A)')RESP
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') THEN
      WRITE(*,'(A\)')' ENTER LINE NUMBER OF COMPONENT TO BE CHANGED -->'
      READ(*,*)INT
      WRITE(*,'(A)')' ENTER NEW MOLE FRACTION'
      WRITE(*,'(A,A,A\)')' ',CN(INT),'  -->'
      READ(*,*)Z1(INT)
      GO TO 12
      ENDIF
   16 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A)')' ***SUMMARY OF INPUT PARAMETERS***'
      WRITE(*,*)
      WRITE(*,'(A,F8.3)')' (1) MOLECULAR WEIGHT OF LIQUID HEAVY+
     *= ',MWC7
      WRITE(*,'(A,F8.6)')' (2) SPECIFIC GRAVITY OF LIQUID HEAVY+
     *= ',SGC7
      WRITE(*,'(A,F8.3)')' (3) MOLECULAR WEIGHT OF VAPOR HEAVY+
     *= ',GMWC7
      WRITE(*,'(A,F8.6)')' (4) SPECIFIC GRAVITY OF VAPOR HEAVY+
     *= ',SGGC7
      WRITE(*,'(A,F8.6)')' (5) SYSTEM GAS-OIL RATIO (SCF/STB)
     *= ',GOR
```

```
      WRITE(*,'(A,F8.2)')' (6) SYSTEM PRESSURE (PSIA)
     *= ',PR
      WRITE(*,'(A,F8.2)')' (7) SYSTEM TEMPERATURE (DEG.F)
     *= ',TR
      WRITE(*,'(A,F8.2)')' (8) EXPERIMENTAL BUBBLE POINT PRESSURE (PSIA)
     *= ',PBEXP
      WRITE(*,*)
      WRITE(*,'(A\)')' DO YOU WANT TO CHANGE ANY INPUT PARAMETERS (Y OR
     *N) ? -->'
      READ(*,'(A)')RESP
      IF(RESP.EQ.'Y'.OR.RESP.EQ.'y') THEN
      WRITE(*,'(A\)')' ENTER LINE NUMBER OF PARAMETER TO BE CHANGED -->'
      READ(*,*)INT
      GOTO(17,18,19,20,40,21,22,23)INT
   17 WRITE(*,'(A\)')' MOLECULAR WEIGHT OF LIQUID HEAVY+ -->'
      READ(*,*)MWC7
      GO TO 16
   18 WRITE(*,'(A\)')' SPECIFIC GRAVITY OF LIQUID HEAVY+ -->'
      READ(*,*)SGC7
      GO TO 16
   19 WRITE(*,'(A\)')' MOLECULAR WEIGHT OF VAPOR HEAVY+ -->'
      READ(*,*)GMWC7
      GO TO 16
   20 WRITE(*,'(A\)')' SPECIFIC GRAVITY OF VAPOR HEAVY+ -->'
      READ(*,*)SGGC7
      GO TO 16
   40 WRITE(*,'(A\)')' SYSTEM GAS-OIL RATIO (SCF/STB) -->'
      READ(*,*)GOR
      GO TO 16
   21 WRITE(*,'(A\)')' SYSTEM PRESSURE (PSIA) -->'
      READ(*,*)PR
      GO TO 16
   22 WRITE(*,'(A\)')' SYSTEM TEMPERATURE (DEG.F) -->'
      READ(*,*)TR
      GO TO 16
   23 WRITE(*,'(A\)')' EXPERIMENTAL BUBBLE POINT PRESSURE (PSIA) -->'
      READ(*,*)PBEXP
      GO TO 16
      ENDIF
   24 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)' ***SUMMARY OF COMPUTATIONAL PARAMETERS***'
      WRITE(*,*)
      WRITE(*,'(A,I1,A)')'  [1]   MULTI-STAGE SEPARATION CALCULATIONS:
     *',NS,' STAGE'
      IF(NS.GT.0) THEN
      WRITE(*,*)'       PRESSURE   TEMPERATURE'
      DO 33 I=1,NS
      WRITE(*,'(9X,F6.1,7X,F5.1)'XPSEP(I),TSEP(I)
```

```
33 CONTINUE
   ENDIF
   WRITE(*,*)
   WRITE(*,'(A,I1)')'  [2]   EQUILIBRIUM RATIO ESTIMATION:-->',METH
   WRITE(*,*)'        (1) SUCCESSIVE SUBSTITUTION'
   WRITE(*,*)'        (2) ACCELERATED SUCCESSIVE SUBSTITUTION'
   WRITE(*,*)
   WRITE(*,*)' [3]   ESTIMATION OF HC-N2 AND HC-CO2       '
   WRITE(*,'(A,I1)')'        BINARY INTERACTION PARAMETERS:-->',IBIN
   WRITE(*,*)'        (1) GRABOWSKI-DAUBERT CORRELATION    '
   WRITE(*,*)'        (2) LAVAL CORRELATION                '
   WRITE(*,*)
   WRITE(*,*)' [4]   PHASE COMPOSITION FILES'
   WRITE(*,'(A,A)')'        FLASH PHASE COMPOSITION:-->',FLSH
   WRITE(*,'(A,A)')'        DIFFERENTIAL PHASE COMPOSITION:-->',DIFF
   WRITE(*,*)
   IF (IOUT.EQ.1) THEN
   WRITE(*,'(A)')'  [5]   OUTPUT:-->PRINTER'
   ELSE
   WRITE(*,'(A,A)')'  [5]   OUTPUT:-->',OUTPUT
   ENDIF
   WRITE(*,*)
   WRITE(*,'(A\)')' DO YOU WANT TO CHANGE ANY COMPUTATIONAL PARAMETER
  *S (Y OR N) ? -->'
   READ(*,'(A)')RESP
   IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') THEN
   WRITE(*,'(A\)')' ENTER LINE NUMBER OF PARAMETER TO BE CHANGED -->'
   READ(*,*)INT
   GOTO(30,8,9,10,11)INT
   ENDIF
   WRITE(*,*)
   WRITE(*,*)
   WRITE(*,*)
   WRITE(*,*)
   WRITE(*,*)
   WRITE(*,*)
   WRITE(*,*)' ************************************************************
  ********'
   WRITE(*,*)' ************************************************************
  ********'
   WRITE(*,*)' **   DO YOU WANT TO SAVE INPUT DATA IN A FILE (Y OR N)
  * ?   **'
   WRITE(*,*)' ************************************************************
  ********'
   WRITE(*,*)' ************************************************************
  ********'
   WRITE(*,*)
   WRITE(*,*)
   WRITE(*,*)
   WRITE(*,'(A\)')' -->'
```

```
      READ(*,'(A)')RESP
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') THEN
      WRITE(*,'(A\)')' NAME OF INPUT FILE (USING PC-DOS STANDARD) -->'
      READ(*,'(A)')INFILE
      OPEN(9,FILE=INFILE,STATUS='NEW')
      WRITE(9,*)INPUTW,(X(I),Y(I),Z1(I),I=1,16),MWC7,SGC7,GMWC7,
     *SGGC7,GOR,PR,TR,PBEXP,METH,IBIN,IOUT
      WRITE(9,'(4A)')FLSH,DIFF,OUTPUT,IPRINT
      WRITE(9,*)NS
      IF (NS.GT.0) THEN
      WRITE(9,*)(PSEP(I),TSEP(I),I=1,NS)
      ENDIF
      ENDIF
      CLOSE (9)
      RETURN
      END
```

```
      SUBROUTINE EXDATA
C
C     PURPOSE : STORE DATA FOR PVT ANLYSIS AND FOR EXAMPLE CALCULATIONS.
C
      COMMON/D1/CN(16)
      COMMON/D2/MW(16),MVOL(16)
      COMMON/D3/W(16),PC(16),TC(16)
      COMMON/D9/D(16,16),IBIN,TB(16),IPB
      COMMON/DAT1/CN1(12),CPT1(4),CZ1(12)
      COMMON/DAT4/CN4(11),CPT4(4),CZ4(11)
      REAL MVOL,MW
      CHARACTER*9 CN
      CN(1)='N2'
      CN(2)='H2S'
      CN(3)='CO2'
      CN(4)='METHANE'
      CN(5)='ETHANE'
      CN(6)='PROPANE'
      CN(7)='I-BUTANE'
      CN(8)='N-BUTANE'
      CN(9)='I-PENTANE'
      CN(10)='N-PENTANE'
      CN(11)='HEXANES'
      CN(12)='HEPTANES'
      CN(13)='OCTANES'
      CN(14)='NONANES'
      CN(15)='DECANES'
      CN(16)='HEAVY+'
      MW(1)=28.013
      MW(2)=34.076
      MW(3)=44.01
      MW(4)=16.043
      MW(5)=30.07
      MW(6)=44.097
      MW(7)=58.124
      MW(8)=58.124
      MW(9)=72.151
      MW(10)=72.151
      MW(11)=86.178
      MW(12)=100.125
      MW(13)=114.232
      MW(14)=128.259
      MW(15)=142.286
      MW(16)=0.0
      MVOL(1)=.5561
      MVOL(2)=.8529
      MVOL(3)=.6911
      MVOL(4)=.8555
      MVOL(5)=1.3528
      MVOL(6)=1.3929
```

```
MVOL(7)=1.655
MVOL(8)=1.5948
MVOL(9)=1.8515
MVOL(10)=1.8328
MVOL(11)=2.0814
MVOL(12)=2.3341
MVOL(13)=2.5921
MVOL(14)=2.85
MVOL(15)=3.1067
MVOL(16)=0.0
W(1)=.04
W(2)=.1
W(3)=.225
W(4)=.0104
W(5)=.0986
W(6)=.1524
W(7)=.1848
W(8)=.201
W(9)=.2223
W(10)=.2539
W(11)=.3007
W(12)=.3498
W(13)=.3942
W(14)=.4455
W(15)=.4885
W(16)=.375
PC(1)=493.024
PC(2)=1306.17
PC(3)=1071.17
PC(4)=667.8
PC(5)=707.8
PC(6)=616.3
PC(7)=529.1
PC(8)=550.7
PC(9)=490.4
PC(10)=488.6
PC(11)=436.9
PC(12)=396.8
PC(13)=360.6
PC(14)=332.
PC(15)=304.
PC(16)=396.8
TC(1)=-232.424
TC(2)=212.717
TC(3)=87.923
TC(4)=-116.63
TC(5)=90.09
TC(6)=206.01
TC(7)=274.98
TC(8)=305.65
```

```
TC(9)=369.1
TC(10)=385.7
TC(11)=453.7
TC(12)=512.8
TC(13)=564.22
TC(14)=610.68
TC(15)=652.1
TC(16)=512.8
TB(1)=139.27
TB(2)=383.066
TB(3)=350.37
TB(4)=201.
TB(5)=332.21
TB(6)=416.02
TB(7)=470.59
TB(8)=490.79
TB(9)=541.81
TB(10)=556.61
TB(11)=615.41
TB(12)=668.86
TB(13)=717.91
TB(14)=763.16
TB(15)=805.17
TB(16)=0.0
END
```

□

APPENDIX B

PVTVO Program Listing

```
C     THOMAS TUFTS
C     PETROLEUM ENGINEERING DEPARTMENT
C
C     PROGRAM PVTVO(INPUT,OUTPUT,TTY,DIFF,FLSH,TAPE7=TTY,TAPE3=DIFF,
C    *TAPE4=FLSH,TAPE8=OUTPUT)
C
C     PURPOSE : TO COMPUTE PVT PROPERTIES OF A VOLATILE OIL SAMPLE
C               WHICH ARE NORMALLY DETERMINED IN THE LABORATORY.
C
C     INPUT PARAMETERS :
C       THE MINIMUM INPUT DATA REQUIRED ARE:
C       PR   = RESERVOIR PRESSURE (PSIA)
C       TR   = RESERVOIR TEMPERATURE (DEG.F)
C       Z1   = FLUID COMPOSITION IN TERMS OF GLOBAL MOLE FRACTION
C       THE ASSOCIATED SUBROUTINES ARE:
C             ACEF,BINT,BUBPT,DATA1,DATA2,DENSL,DOUT,DVAP,EQR,
C             FLASH,KCOR,MOLES,PHASEB,QROOT,VISCG,VISCL
C
C     OUTPUT PARAMETERS :
C       APID = API GRAVITY OF LIQUID AT EACH DIFFERENTIAL VAP. STAGE
C       APIF = API GRAVITY OF LIQUID AT EACH FLASH VAP. STAGE
C       BGD  = GAS FORMATION VOLUME FACTOR AT EACH DIFFERENTIAL VAP.
C              STAGE (CU.FT/SCF)
C       BGF  = GAS FORMATION VOLUME FACTOR AT EACH FLASH VAP. STAGE
C              (CU.FT/SCF)
C       BOD  = RELATIVE OIL VOLUME AT EACH DIFFERENTIAL VAP. STAGE
C              (BBL/STB)
C       BOF  = RELATIVE OIL VOLUME AT EACH FLASH VAP. STAGE (BBL/STB)
C       BTD  = TOTAL FORMATION VOLUME FACTOR AT EACH DIFFERENTIAL
C              VAP. STAGE (BBL/STB)
C       BTF  = TOTAL FORMATION VOLUME FACTOR AT EACH FLASH VAP. STAGE
C              (BBL/STB)
C       DENLD = LIQUID DENSITY AT EACH DIFFERENTIAL VAP. STAGE
C              (LB/CU.FT)
C       DENLF = LIQUID DENSITY AT EACH FLASH VAP. STAGE (LB/CU.FT)
C       ELCE = EQUIVALENT LIQUID CONTENT IN GAS PHASE-ETHANE (GPM)
C       ELCP = EQUIVALENT LIQUID CONTENT IN GAS PHASE-PROPANE (GPM)
C       ELCB = EQUIVALENT LIQUID CONTENT IN GAS PHASE-BUTANES (GPM)
C       ELCPE = EQUIVALENT LIQUID CONTENT IN GAS PHASE-PENTANE PLUS
C              (GPM)
C       FGP1 = GAS PHASE PRODUCED (MSCF)
C       FVF  = RATIO OF OIL VOLUME AT SATURATION TO OIL VOLUME AT
C              STANDARD CONDITIONS (BBL/STB)
C       GOR1 = RATIO OF VOLUME OF GAS AT 14.7 PSIA AND 60 DEG.F TO
C              VOLUME OF OIL AT GIVEN PRESSURE AND TEMPERATURE
C              (SCF/BBL)
C       GOR2 = RATIO OF VOLUME OF GAS AT 14.7 PSIA AND 60 DEG.F TO
C              VOLUME OF OIL AT 14.7 PSIA AND 60 DEG.F
C       P    = PRESSURE (PSIA)
C       PB   = CALCULATED BUBBLE POINT PRESSURE (PSIA)
```

```
C       PBEXP = EXPERIMENTAL BUBBLE POINT PRESSURE (PSIA)
C       PP2  = PLANT PRODUCT-ETHANE (GAL)
C       PP3  = PLANT PRODUCT-PROPANE (GAL)
C       PP4  = PLANT PRODUCT-BUTANES (GAL)
C       PP5  = PLANT PRODUCT-PENTANE PLUS (GAL)
C       PSEP = SEPARATOR PRESSURE (PSIG)
C       RSD  = SOLUTION GAS-OIL RATIO AT EACH DIFFERENTIAL VAP. STAGE
C              (SCF/STB)
C       RSF  = SOLUTION GAS-OIL RATIO AT EACH FLASH VAP. STAGE
C              (SCF/STB)
C       RV   = RELATIVE VOLUME, I.E. RATIO OF FLUID VOLUME AT GIVEN
C              FLASH VAP. STAGE TO FLUID VOLUME AT SATURATION
C       RVD  = RELATIVE VOLUME AT EACH DIFFERENTIAL VAP. STAGE
C       SGGD = GAS SPECIFIC GRAVITY AT EACH DIFFERENTIAL VAP. STAGE
C              (AIR=1)
C       SGGF = GAS SPECIFIC GRAVITY AT EACH FLASH VAP. STAGE (AIR=1)
C       SGGS = GAS SPECIFIC GRAVITY DURING MULTI-STAGE SEPARATION
C              (AIR=1)
C       SNL  = LIQUID MOLE FRACTION AT EACH SEPARATOR STAGE
C       SVF  = SEPARATOR OIL VOLUME FACTOR (BBL/STB)
C       TSEP = SEPARATOR TEMPERATURE (DEG.F)
C       VISGD = GAS VISCOSITY AT EACH DIFFERENTIAL VAP. STAGE (CP)
C       VISGF = GAS VISCOSITY AT EACH FLASH VAP. STAGE (CP)
C       VISOD = OIL VISCOSITY AT EACH DIFFERENTIAL VAP. STAGE (CP)
C       VISOF = OIL VISCOSITY AT EACH FLASH VAP. STAGE (CP)
C       VLS  = LIQUID MOLAR VOLUME AT EACH SEPARATOR STAGE
C              (CU.FT/LB-MOLE)
C       ZVD  = GAS COMPRESSIBILITY/DEVIATION FACTOR AT EACH
C              DIFFERENTIAL VAP. STAGE
C       ZVF  = GAS COMPRESSIBILITY/DEVIATION FACTOR AT EACH FLASH
C              VAP. STAGE
C
C     OTHER PARAMETERS :
C       DIF  = DIFFERENCE BETWEEN CALCULATED AND EXPERIMENTAL BUBBLE
C              POINT PRESSURE (PSIA)
C       DLR  = LIQUID MOLE FRACTION REMAINING AT FINAL DIFFERENTIAL
C              VAP. STAGE
C       DLS  = LIQUID MOLE FRACTION AT EACH DIFFERENTIAL VAP.
C              STAGE
C       FLR  = LIQUID MOLE FRACTION REMAINING AT FINAL FLASH VAP.
C              STAGE
C       FLS  = LIQUID MOLE FRACTION AT EACH FLASH VAP. STAGE
C       IT1, IT2, ETC = NO. OF ITERATIONS
C       NG   = GAS MOLE FRACTION AT EACH FLASH VAP. STAGE
C       NGD  = GAS MOLE FRACTION AT EACH DIFFERENTIAL VAP. STAGE
C       NL   = LIQUID MOLE FRACTION AT EACH FLASH VAP. STAGE
C       NLD  = LIQUID MOLE FRACTION AT EACH DIFFERENTIAL VAP. STAGE
C       NLDM = LIQUID MOLE FRACTION AT EACH DIFFERENTIAL VAP. STAGE
C       P    = PRESSURE (PSIA)
C       PP   = PRESSURE AT EACH DIFFERENTIAL OR FLASH VAP. STAGE
```

```
C              (PSIA)
C       TMGP = TOTAL MOLES OF GAS PHASE PRODUCED
C       TMLD = TOTAL MOLES OF LIQIUD REMAINING AT EACH DIFFERENTIAL
C              VAP. STAGE
C       TMLS = TOTAL MOLES OF LIQUID REMAINING AT EACH CONSTANT
C              VOLUME DEPLETION STAGE
C       VD   = LIQUID MOLAR VOLUME AT EACH DIFFERENTIAL VAP. STAGE
C              (CU.FT/LB-MOLE)
C       VF   = LIQUID MOLAR VOLUME AT EACH FLASH VAP. STAGE
C              (CU.FT/LB-MOLE)
C       VGF1 = GAS VOLUME AT EACH FLASH VAP. STAGE (CU.FT)
C       Z2   = COMPONENT MOLE FRACTION
C       Z3   = COMPONENT MOLE FRACTION
C       Z4   = COMPONENT MOLE FRACTION
C       Z5   = COMPONENT MOLE FRACTION
C       Z6   = COMPONENT MOLE FRACTION
C
C     FLAG :
C       ID    = TYPE OF FLUID SYSTEM. ID=1 INDICATES BLACK/VOLATILE
C               OIL; ID=3 INDICATES RETROGRADE CONDENSATE SYSTEM.
C       IBIN  = CHOICE OF CORRELATION USED TO ESTIMATE BINARY
C               INTERACTION PARAMETERS (BIP). IBIN=1 INDICATES
C               USE OF GRABOWSKI-DAUBERT CORRELATION FOR H/C-CO2
C               AND H/C-N2 BIP. IBIN=2 INDICATES THE USE OF LAVAL'S
C               CORRELATION FOR SIMILAR BIP.
C       ISEP  = INDICATES TYPE OF FLUID VAP. CALCULATIONS. ISEP=0
C               INDICATES FLASH VAP. AND ISEP=2 INDICATES
C               DIFFERENTIAL VAP. CALCULATIONS.
C       IPRINT = INDICATES WHETHER OUTPUT ON FLUID COMPOSITION IS
C               FILED OR NOT. IPRINT=Y INDICATES THE OUTPUT IS
C               FILED WHEREAS IPRINT=N INDICATES NO FILES.
C       METH  = METHOD USED IN EQUILIBRIUM RATIO ESTIMATION.
C               METH=1 INDICATES USE OF SUCCESSIVE SUBSTITUTION AND
C               METH=2 INDICATES USE OF ACCELERATED SUCCESSIVE
C               SUBSTITUTION
C       MLG   = CALCULATIONS USED IN SUB. DENSL. MLG=1 INDICATES
C               CALC. OF LIQUID MOLAR VOLUME AND DENSITY. MLG=2
C               INDICATES CALC. OF GAS SPECIFIC GRAVITY
C       MS    = TEMPERATURE AND PRESSURE CONDITIONS. MS=0 INDICATES
C               CONDITIONS AT GIVEN P & T. MS=1 INDICATES STANDARD
C               CONDITIONS (14.7 PSIA & 60 DEG.F). MS=2 INDICATES
C               CONDITIONS AT 14.7 PSIA & GIVEN TEMP.
C
      COMMON/D1/CN(16)
      COMMON/D2/MW(16),MVOL(16)
      COMMON/D3/W(16),PC(16),TC(16)
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D5/Z(16),X(16),Y(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D7/ZL,ZV
```

```
      COMMON/D8/PB,PBEXP
      COMMON/D9/D(16,16),IBIN,TB(16)
      COMMON/D10/NG,NL,SUMX,SUMY
      COMMON/D11/ID,MM
      COMMON/D12/ISEP,NCOM,P1
      COMMON/D13/GMWC7,SGGC7,MWC7,SGC7
      COMMON/D14/VL,DENL,SGG,HLG,HS,Z2(16)
      COMMON/D15/IKV,METH
      COMMON/D16/NGD,NLD,XD(16),YD(16),SUMXD,SUMYD,SUMZD
      COMMON/D20/INPUTH,GOR,IOUT,FLSH,DIFF,OUTPUT,PSEP(5),TSEP(5)
      COMMON/D21/IPRINT
      COMMON/D22/MS
      DIMENSION APIF(100),BOF(100),BGF(100),BTF(100),DENF(100),
     *SGGF(100),TMGF(100),VF(100),VGF(100),TMLD(100),RVD(100),
     *VISGF(100),VISOF(100),ELCE(100),ELCP(100),ELCB(100),ELCPE(100),
     *RSF(100),X1(16),Y1(16),Z4(16),Z5(16),Z6(16),ZVF(100),
     *APID(100),BOD(100),BGD(100),BTD(100),DENLD(100),SGGD(100),
     *HLDM(100),VD(100),VISGD(100),VISOD(100),RSD(100),ZVD(100),
     *DIF(20),TMLS(100),TMGP(100),SNL(10),VLS(10),
     *SGGS(10),GOR1(10),GOR2(10),SVF(10)
      REAL K,NG,NL,NL1,NGD,NLD,NLDM,MW,MWC7,MVOL
      CHARACTER*1 IPRINT
      CHARACTER*9 CN
      CHARACTER*14 FLSH,DIFF,OUTPUT
      DATA R/10.731/
$DEBUG
      OPEN (7,FILE='CON')
      CALL EXDATA
      CALL INPUT
      OPEN (8,FILE=OUTPUT,STATUS='NEW')
      IF (IPRINT.EQ.'Y'.OR.IPRINT.EQ.'y') THEN
       OPEN (3,FILE=DIFF,STATUS='NEW')
       OPEN (4,FILE=FLSH,STATUS='NEW')
      ENDIF
C     SELECT ITERATIVE METHOD OF K-VALUE ESTIMATION.
    5 WRITE(7,1011)
      WRITE(8,1011)
      SUMZ=0.
      CALL DATA1
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'          ****************************'
      WRITE(*,*)'          *** PROGRAM IN PROGRESS ***'
      WRITE(*,*)'          ***    PLEASE WAIT.     ***'
      WRITE(*,*)'          ****************************'
      WRITE(*,*)'          ****** 5-30 MINUTES *******'
      WRITE(*,*)'          ****************************'
      WRITE(*,*)
      WRITE(*,*)
```

```
      WRITE(*,*)
    6 WRITE(8,1012)
      IF (METH.EQ.1) THEN
        WRITE(8,1015)
      ELSE
        WRITE(8,1016)
      ENDIF
      IF (IBIN.EQ.1) THEN
        WRITE(8,1017)
      ELSE
        WRITE(8,1018)
      ENDIF
   16 CALL BINT
      WRITE(7,1031)TR,PR
      WRITE(8,1031)TR,PR
      IF (PBEXP.LT.1.0) THEN
        WRITE(7,1032)
        WRITE(8,1032)
      ELSE
        WRITE(7,1033)PBEXP
        WRITE(8,1033)PBEXP
      ENDIF
      WRITE(7,1034)
      WRITE(8,1034)
      DO 18 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 18
              WRITE(7,1035)CN(I),Z1(I)
              WRITE(8,1035)CN(I),Z1(I)
   18 CONTINUE
      IF (Z1(16).LT.1.E-25) GO TO 19
      WRITE(7,1036)MWC7,SGC7
      WRITE(8,1036)MWC7,SGC7
   19 IF (PBEXP.GT.1.0) GO TO 20
C     DETERMINE TYPE OF FLUID.
      CALL PHASEB
      IF ((ID.EQ.0).OR.(ID.GT.2)) GO TO 400
C     CALCULATE BUBBLE POINT PRESSURE (EXPERIMENTAL VALUE UNKOWN).
      P=14.7
      CALL BUBPT
      GO TO 50
C     CALCULATE BUBBLE POINT PRESSURE (EXPERIMENTAL VALUE KNOWN).
   20 IF (MM.EQ.1) THEN
        D(4,16)=0.0609
        D(16,4)=0.0609
      ENDIF
      IF (MM.EQ.2) THEN
        D(4,16)=0.0798
        D(16,4)=0.0798
      ENDIF
      P=PBEXP
```

```
      CALL BUBPT
      IF ((ABS(PBEXP-PB).LE.25.).OR.(Z1(16).LT.1.E-25)) GO TO 50
      DMIN=0.1
      DO 40 I=1,10
           IF (I.EQ.1) GO TO 32
           D(4,16)=D(4,16)+0.02
           D(16,4)=D(16,4)+0.02
           CALL BUBPT
   32      DIF(I)=PB-PBEXP
           IF(I.EQ.1) GO TO 35
           IF (ABS(DIF(I)).GE.ABS(DMIN)) GO TO 45
   35      DMIN=DIF(I)
           BIN=D(4,16)
           WRITE(7,1040)BIN,DMIN,PB
   40 CONTINUE
   45 D(4,16)=BIN
      D(16,4)=BIN
      PB=PBEXP+DMIN
   50 WRITE(7,1045)PB
      WRITE(8,1045)PB
   52 P=PB
      PP=PB
      MS=0
      TMG=0.
      DO 55 I=1,16
           Z3(I)=Z1(I)
           Z4(I)=Z1(I)
           Z5(I)=Z1(I)
           Z6(I)=Z1(I)
   55 CONTINUE
C
C     PERFORM PRESSURE DEPLETION CALCULATIONS.
      DO 150 IT=1,100
           IF (IT.EQ.1) GO TO 62
C          FLASH SEPARATION OF LIQUID PHASE.
           DO 61 I=1,16
                Z1(I)=Z5(I)
   61      CONTINUE
   62      IT1=1
           CALL KCOR
   65      CALL FLASH
           CALL MOLES
           CALL EQR
           IF (ABS(SUMER).LT.1.E-5) GO TO 80
           IF (IT1.GE.100) GO TO 70
           IT1=IT1+1
           GO TO 65
   70      WRITE(7,1050)IT1
           WRITE(4,1050)IT1
           GO TO 400
```

```
   80       NL1=NL
            ZF=ZL
            SX=SUMX
            DO 85 I=1,16
                 X1(I)=X(I)
                 Y1(I)=Y(I)
                 Z(I)=Z1(I)
   85       CONTINUE
            IF (IPRINT.GT.1) GO TO 87
            IF (IT.GT.1) GO TO 86
            WRITE(4,1011)
            WRITE(4,1070)
   86       ISEP=0
            P1=PP
            CALL DOUT
   87       IF (IT.GT.2) GO TO 93
            DO 90 I=1,16
                 Z1(I)=X(I)
                 Z2(I)=X(I)
                 Z4(I)=Y(I)
   90       CONTINUE
            NL=0.
            GO TO 130
C           FLASH SEPARATION OF THE VAPOR PHASE.
   93       DO 95 I=1,16
                 Z1(I)=Z4(I)
                 Z(I)=Z4(I)
   95       CONTINUE
            IT2=1
            CALL KCOR
  100       CALL FLASH
            CALL MOLES
            CALL EQR
            IF (ABS(SUMER).LT.1.E-5) GO TO 110
            IF (IT2.GE.100) GO TO 105
            IT2=IT2+1
            GO TO 100
  105       WRITE(7,1050)IT2
            WRITE(4,1050)IT2
            GO TO 400
  110       IF (IPRINT.GT.1) GO TO 117
            IF (IT.GT.1) GO TO 115
            WRITE(3,1011)
            WRITE(4,1080)
  115       ISEP=0
            P1=PP
            CALL DOUT
  117       DO 120 I=1,16
                 Z1(I)=(NL*X(I)+NL1*X1(I))/(NL+NL1)
                 Z4(I)=((1.-NL)*Y(I)+(1.-NL1)*Y1(I))/(2.-NL-NL1)
```

```
            Z2(I)=Z1(I)
  120       CONTINUE
  130       ZL=ZF
            SUMX=SX
C           CALCULATE LIQUID MOLAR VOLUME AND  DENSITY OF THE
C           FLASHED FLUID.
            MLG=1
            CALL DENSL
            DENF(IT)=DENL
            IF (IT.EQ.1) TML=100./VL
            TML=TML*NL1+TMG*NL
            TMLS(IT)=TML
            VF(IT)=TML*VL
            DO 133 I=1,16
                 Z2(I)=Z4(I)
  133       CONTINUE
C           CALCULATE GAS SPECIFIC GRAVITY AND VISCOSITY OF THE
C           FLASHED FLUID.
            MLG=2
            CALL DENSL
            ZUF(IT)=ZU
            SGGF(IT)=SGG
            CALL VISCG(P,T,SGG,ZU,VISG)
            VISGF(IT)=VISG
C           BRING GAS TO ORIGINAL VOLUME.
            VGF(IT)=100.-VF(IT)
            TMG=VGF(IT)*P/(ZUF(IT)*R*(T+460.))
            TMGF(IT)=TMG
            IF ((IT.LT.3).OR.(IPRINT.GT.1)) GO TO 138
            TM=TML+TMG
            NL=TML/TM
            NG=TMG/TM
            DO 137 I=1,16
                 X(I)=Z1(I)
                 Y(I)=Z4(I)
                 Z(I)=NG*Z4(I)+NL*Z1(I)
  137       CONTINUE
            ISEP=0
            P1=PP
            CALL DOUT
  138       DO 139 I=1,16
                 Z5(I)=Z1(I)
  139       CONTINUE
C           CALCULATE INSTANTANEOUS LIQUID RECOVERY DURING DEPLETION
C           (FLASH SEPARATION).
            IF (GMWC7.LT.1.) GO TO 127
            SUMV=0.
            DO 125 I=5,15
                 IF (Z4(I).LT.1.E-25) GO TO 125
                 SUMV=SUMV+MVOL(I)*Z4(I)*19.715
```

```
  125       CONTINUE
            IF (Z4(16).LT.1.E-25) GO TO 126
            SUMV=SUMV+GMWC7*Z4(16)*19.715/(62.4*SGGC7)
  126       ELCE(IT)=SUMV
            ELCP(IT)=SUMV-MVOL(5)*Z4(5)*19.715
            ELCB(IT)=ELCP(IT)-MVOL(6)*Z4(6)*19.715
            ELCPE(IT)=ELCB(IT)-(MVOL(7)*Z4(7)+MVOL(8)*Z4(8))*19.715
C           DIFFERENTIAL SEPARATION OF FLUID.
  127       IT3=1
            DO 128 I=1,16
                 Z1(I)=Z3(I)
  128       CONTINUE
            CALL KCOR
  201       CALL DVAP
            DO 199 I=1,16
                 X(I)=XD(I)
                 Y(I)=YD(I)
  199       CONTINUE
            CALL EQR
            IF (ABS(SUMER).LT.1.E-5) GO TO 205
            IF (IT3.GE.100) GO TO 203
            IT3=IT3+1
            GO TO 201
  203       WRITE(7,1050)IT3
            WRITE(3,1050)IT3
            GO TO 400
  205       IF (IPRINT.GT.1) GO TO 197
            ISEP=2
            P1=PP
            CALL DOUT
  197       NLDM(IT)=NLD
            IF (NLD.LE.0.) GO TO 207
C           CALCULATE LIQUID MOLAR VOLUME AND DENSITY OF THE
C           DIFFERENTIALLY SEPARATED FLUID.
            DO 206 I=1,16
                 Z2(I)=XD(I)
                 Z3(I)=XD(I)
  206       CONTINUE
            MLG=1
            CALL DENSL
            VD(IT)=VL
            DENLD(IT)=DENL
            GO TO 208
  207       VD(IT)=0.
            DENLD(IT)=0.
  208       IF (NLD.GE.1.) GO TO 210
C           CALCULATE GAS SPECIFIC GRAVITY AND VISCOSITY OF THE
C           DIFFERENTIALLY SEPARATED FLUID.
            DO 209 I=1,16
                 Z2(I)=YD(I)
```

```
  209       CONTINUE
            MLG=2
            CALL DENSL
            GO TO 211
  210       ZV=0.
            SGG=0.
  211       ZVD(IT)=ZV
            SGGD(IT)=SGG
            CALL VISCG(P,T,SGG,ZV,VISG)
            VISGD(IT)=VISG
            IF (MS.EQ.1) GO TO 160
            P=PP-100.
            PP=PP-200.
            IF (PP.LT.100.) GO TO 140
            GO TO 150
  140       MS=1
            P=14.7
            T=60.
  150 CONTINUE
C     CALCULATE OIL FORMATION VOLUME FACTOR AND SOLUTION GAS-OIL
C     RATIO OF THE FLASHED AND DIFFERENTIALLY SEPARATED FLUID.
  160 P=PB
      T=TR
      MS=0
      ZVF(1)=0.
      SGGF(1)=0.
      VISGF(1)=0.
      DLR=1.
      DLS=1.
      DO 163 I=1,IT
           DLR=DLR*MLDM(I)
  163 CONTINUE
      DO 165 I=1,IT
           DLS=DLS*MLDM(I)
           TMLD(I)=DLS
           BOD(I)=VD(I)*DLS/(VD(IT)*DLR)
           BOF(I)=VF(I)/VF(IT)
           TMGP(I)=TMLS(1)-TMLS(I)-TMGF(I)
  165 CONTINUE
      DO 168 I=1,IT
           RSD(I)=(TMLD(I)-TMLD(IT))*2130./(VD(IT)*DLR)
           RSF(I)=(TMLS(I)-TMLS(IT))*2130./VF(IT)
  168 CONTINUE
C     CALCULATE OIL VISCOSITY.
      DENSF=DENF(IT)
      DENSD=DENLD(IT)
      CALL VISCL(DENSF,T,RSF,VISOF,IT)
      CALL VISCL(DENSD,T,RSD,VISOD,IT)
C     CALCULATE GAS FORMATION VOLUME FACTOR,TOTAL FORMATION VOLUME
C     FACTOR,OIL RELATIVE DENSITY AND API GRAVITY,AND RELATIVE VOLUME
```

```
C     OF THE FLASHED FLUID.
      WRITE(7,1310)
      WRITE(8,1310)
      WRITE(7,1100)
      WRITE(8,1100)
      DO 175 I=1,IT
            BGF(I)=0.0282*ZUF(I)*(T+460.)/P
            BTF(I)=BOF(I)+(BGF(I)*(RSF(1)-RSF(I)))/5.615
            DENF(I)=DENF(I)/62.4
            APIF(I)=141.5/DENF(I)-131.5
            RV=(VF(I)+VGF(I)+TMGP(I)*ZUF(I)*R*(T+460.)/P)/VF(1)
            WRITE(7,1110)P,T,RSF(I),BOF(I),BTF(I),APIF(I),DENF(I),
     *      ZUF(I),BGF(I),SGGF(I),VISOF(I),VISGF(I),RV
            WRITE(8,1110)P,T,RSF(I),BOF(I),BTF(I),APIF(I),DENF(I),
     *      ZUF(I),BGF(I),SGGF(I),VISOF(I),VISGF(I),RV
            IF (MS.EQ.1) GO TO 180
            IF (I.EQ.IT-1) GO TO 170
            P=P-200.
            GO TO 175
  170       MS=1
            P=14.7
            T=60.
  175 CONTINUE
C     CALCULATE CUMULATIVE RECOVERY DURING DEPLETION
C     (FLASH SEPARATION).
  180 IF (GMWC7.LT.1.) GO TO 195
      P=PB
      T=TR
      MS=0
      WRITE(7,1120)
      WRITE(8,1120)
      DO 190 I=1,IT
            FGP1=TMGP(I)*1000./TMLS(1)
            FPP5=ELCPE(I)*FGP1
            FPP4=(ELCB(I)-ELCPE(I))*FGP1
            FPP3=(ELCP(I)-ELCB(I))*FGP1
            FPP2=(ELCE(I)-ELCP(I))*FGP1
            WRITE(7,1130)P,VF(I),FGP1,FPP2,FPP3,FPP4,FPP5,ELCE(I),
     *      ELCP(I),ELCB(I),ELCPE(I)
            WRITE(8,1130)P,VF(I),FGP1,FPP2,FPP3,FPP4,FPP5,ELCE(I),
     *      ELCP(I),ELCB(I),ELCPE(I)
            IF (MS.EQ.1) GO TO 195
            IF (I.EQ.IT-1) GO TO 185
            P=P-200.
            GO TO 190
  185       MS=1
            P=14.7
            T=60.
  190 CONTINUE
C     CALCULATE GAS FORMATION VOLUME FACTOR,TOTAL FORMATION VOLUME
```

```
C     FACTOR,OIL RELATIVE DENSITY AND API GRAVITY,AND RELATIVE VOLUME
C     OF THE DIFFERENTIALLY SEPARATED FLUID.
  195 P=PB
      T=TR
      MS=0
      WRITE(7,1315)
      WRITE(8,1315)
      WRITE(7,1100)
      WRITE(8,1100)
      DO 245 I=1,IT
            BGD(I)=0.0282*ZUD(I)*(T+460.)/P
            BTD(I)=BOD(I)+(BGD(I)*(RSD(1)-RSD(I)))/5.615
            DENLD(I)=DENLD(I)/62.4
            APID(I)=141.5/DENLD(I)-131.5
            RVD(I)=(VD(I)*TMLD(I)+(1.-TMLD(I))*ZUD(I)*R*(T+460.)/P)
     *            /VD(1)
            WRITE(7,1110)P,T,RSD(I),BOD(I),BTD(I),APID(I),DENLD(I),
     *      ZUD(I),BGD(I),SGGD(I),VISOD(I),VISGD(I),RVD(I)
            WRITE(8,1110)P,T,RSD(I),BOD(I),BTD(I),APID(I),DENLD(I),
     *      ZUD(I),BGD(I),SGGD(I),VISOD(I),VISGD(I),RVD(I)
            IF (MS.EQ.1) GO TO 248
            IF (I.EQ.IT-1) GO TO 244
            P=P-200.
            GO TO 245
  244       P=14.7
            MS=1
            T=60.
  245 CONTINUE
C     MULTI-STAGE SEPARATION SIMULATION:
C     - FLASH CALCULATIONS ARE PERFORMED AT GIVEN PRESSURE AND
C      TEMPERATURE OF EACH SEPARATOR.
  248 DO 300 I=1,16
            Z1(I)=Z6(I)
  300 CONTINUE
  305 MS=0
      IF (NS.EQ.0) GO TO 400
      DO 350 IS=1,NS+1
            IT4=1
            IF (MS.EQ.1) GO TO 307
            P=PSEP(IS)
            T=TSEP(IS)
            IF (P.LT.2.) GO TO 400
            PSEP(IS)=P-14.7
            TSEP(IS)=T
  307       ISEP=0
            CALL KCOR
  310       CALL FLASH
            CALL MOLES
            CALL EQR
            IF (ABS(SUMER).LT.1.E-5) GO TO 330
```

```
            IF (IT4.GE.100) GO TO 325
            IT4=IT4+1
            GO TO 310
  325       WRITE(7,1050)IT4
            WRITE(4,1050)IT4
            GO TO 400
  330       IF (IPRINT.GT.1) GO TO 337
            IF (IS.GT.1) GO TO 332
            WRITE(8,1209)
  332       DO 336 I=1,16
                 Z(I)=Z1(I)
  336       CONTINUE
            P1=P
            CALL DOUT
  337       SNL(IS)=1.-NG
C           CALCULATE LIQUID MOLAR VOLUME AND DENSITY.
            DO 340 I=1,16
                 Z1(I)=X(I)
                 Z2(I)=X(I)
  340       CONTINUE
            MLG=1
            CALL DENSL
            VLS(IS)=VL
            IF (NS.EQ.0) GO TO 342
            DENO=DENL
  342       IF (NG.LE.0.) GO TO 347
C           CALCULATE GAS SPECIFIC GRAVITY.
            DO 345 I=1,16
                 Z2(I)=Y(I)
  345       CONTINUE
            MLG=2
            CALL DENSL
            GO TO 348
  347       SGG=0.
  348       SGGS(IS)=SGG
            IF (NS.EQ.1) GO TO 355
            IF (IS.NE.NS) GO TO 350
            P=14.7
            T=60.
            NS=1
  350 CONTINUE
C     CALCULATE OIL FORMATION VOLUME FACTOR AND SOLUTION GAS-OIL
C     RATIO.
  355 FLS=1.
      FLR=1.
      DO 360 I=1,IS
           FLR=FLR*SNL(I)
  360 CONTINUE
      DO 365 I=1,NS
           FLS=FLS*SNL(I)
```

```
          GOR1(I)=(1.-SNL(I))*2130./(SNL(I)*ULS(I))
          GOR2(I)=(1.-SNL(I))*2130./(ULS(IS)*FLR)
          SUF(I)=ULS(I)*FLS/(ULS(IS)*FLR)
 365 CONTINUE
     TOAPI=141.5*62.4/DENO-131.5
     FVF=ULS(1)*SNL(1)/(ULS(IS)*FLR)
     WRITE(7,1220)
     WRITE(8,1220)
     DO 380 I=1,NS
     IF (I.EQ.NS) GO TO 370
     WRITE(7,1230)PSEP(I),TSEP(I),GOR1(I),GOR2(I),SUF(I),SGGS(I)
     WRITE(8,1230)PSEP(I),TSEP(I),GOR1(I),GOR2(I),SUF(I),SGGS(I)
     GO TO 380
 370       WRITE(7,1240)PSEP(I),TSEP(I),GOR1(I),GOR2(I),TOAPI,FVF,
    *      SUF(I),SGGS(I)
          WRITE(8,1240)PSEP(I),TSEP(I),GOR1(I),GOR2(I),TOAPI,FVF,
    *      SUF(I),SGGS(I)
 380 CONTINUE
     WRITE(7,1260)
     WRITE(8,1260)
 400 CONTINUE
 500 STOP

1011 FORMAT(/20X,29('*'),/20X,'*',1X,'VOLATILE OIL PVT ANALYSIS',1X,'*'
    *,/20X,29('*'))
1012 FORMAT(/3X,'METHOD/CORRELATION USED',10X,'PURPOSE',/3X,23('-'),
    *10X,7('-'))
1017 FORMAT(3X,'GRABOWSKI-DAUBERT',16X,'N2-H/C,CO2-H/C AND H2S-H/C BINA
    *RY',/,36X,'INTERACTION PARAMETERS ESTIMATION')
1018 FORMAT(3X,'LAWAL',28X,'N2-H/C AND CO2-H/C BINARY',/,36X,
    *'INTERACTION PARAMETERS ESTIMATION',/3X,'GRABOWSKI-DAUBERT',
    *16X,'H2S-H/C BINARY INTERACTION',/,36X,'PARAMETERS ESTIMATION')
1015 FORMAT(3X,'SUCCESSIVE SUBSTITUTION',10X,'ITERATIVE ESTIMATION OF K
    *-VALUES')
1016 FORMAT(3X,'ACCD. SUCCESSIVE SUBSTITUTION',4X,'ITERATIVE ESTIMATIO
    *N OF K-VALUES')
1040 FORMAT(/3X,'WHEN METHANE-HEAVY+ INTERACTION FACTOR = ',3X,F6.4,
    */20X,'PRES.DIFFERENCE = ',3X,F8.2,2X,'PSIA',/20X,
    *'EST.BUBBLE POINT PRES. = ',3X,F7.2,2X,'PSIA')
1045 FORMAT(/3X,'CALCULATED BUBBLE POINT PRESSURE = ',3X,F7.2,2X,
    *'PSIA')
1080 FORMAT(/3X,'FLASH SEPARATION OF VAPOR PHASE :',/3X,'----------
    *----------')
1070 FORMAT(/3X,'FLASH SEPARATION OF LIQUID PHASE :',/3X,'----------
    *----------')
1100 FORMAT(132(1H-),/23X,'SOLN',8X,'OIL',7X,'TOTAL',6X,'DEG',6X,'OIL',
    *7X,'Z',11X,'GAS',8X,'GAS',5X,'OIL',5X,'GAS',5X,'RELATIVE',/2X,
    *'PRES',6X,'TEMP',8X,'GOR',8X,'FVF',8X,'FVF',7X,'API',4X,'DENSITY',
    *3X,'FACTOR',8X,'FVF',6X,'GRAVITY',3X,'VISC',4X,'VISC',4X,'VOLUME',
    */1X,'(PSIA)',4X,'(DEG.F)',3X,'(SCF/STB)',2X,'(BBL/STB)',2X,
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     *'(BBL/STB)',11X,'(GM/CC)',13X,'(CU.FT/SCF)',2X,'(AIR=1)',3X,
     *'(CP)',4X,'(CP)',/)
1110 FORMAT(1X,F6.1,5X,F5.1,5X,F6.1,6X,F5.3,5X,F7.3,4X,F5.1,4X,F6.4,
     *4X,F5.3,6X,F6.4,6X,F5.3,3X,F5.3,3X,F6.4,3X,F7.3)
1120 FORMAT(1H1,/34X,'CUMULATIVE RECOVERY DURING DEPLETION',/37X,
     *'(PER MMSCF OF ORIGINAL FLUID)',/,115('-'),/3X,'RESERVOIR',2X,
     *'LIQUID',/3X,'PRESSURE',3X,'VOLUME',
     *3X,'GAS PHASE',4X,'PLANT PRODUCTS IN GAS PHASE,GALLONS',
     *24X,'GPM',/4X,'(PSIA)',5X,'(%)',6X,'(MSCF)',6X,'ETHANE',3X,
     *'PROPANE',3X,'BUTANES',3X,'PENTANES+',3X,'ETHANE+',3X,'PROPANE+',
     *3X,'BUTANE+',3X,'PENTANE+',/)
1130 FORMAT(4X,F6.1,4X,F5.1,5X,F7.2,5X,F5.0,5X,F5.0,5X,F5.0,5X,F5.0,
     *6X,F5.2,5X,F5.2,6X,F5.2,5X,F5.2)
1050 FORMAT(//3X,'K-VALUES DO NOT CONVERGE AFTER = ',3X,I3,2X,
     *'ITERATIONS.')
1031 FORMAT(/3X,'INITIAL RESERVOIR CONDITIONS AND COMPOSITION (GIVEN)',
     */3X,'-----------------------------------------------',/3X,
     *'RESERVOIR TEMPERATURE = ',3X,F5.1,3X,'DEG.F',/3X,
     *'RESERVOIR PRESSURE    = ',3X,F7.2,2X,'PSIA')
1032 FORMAT(3X,'BUBBLE POINT PRESSURE (EXPT.) = NOT GIVEN')
1033 FORMAT(3X,'BUBBLE POINT PRESSURE (EXPT.) = ',3X,F7.2,2X,'PSIA')
1034 FORMAT(//3X,'COMPONENT',18X,
     *'MOLE FRACTION',/3X,'---------',18X,'-------------')
1035 FORMAT(3X,A9,20X,F7.5)
1036 FORMAT(/3X,'HEAVY-PLUS:MOLECULAR WEIGHT = ',3X,F4.0,
     */16X,'SPECIFIC GRAVITY = ',3X,F7.5,/)
1209 FORMAT(1H1,/3X,'MULTI-STAGE SEPARATOR CALCULATIONS',/3X,
     *'-----------------------------------')
1220 FORMAT(1H1,/3X,'SEPARATOR',11X,'GAS/OIL',2X,'GAS/OIL',2X,
     *'TANK OIL',2X,'FORMATION',2X,'SEPARATOR',/3X,'PRESSURE',4X,
     *'TEMP.',4X,'RATIO',4X,'RATIO',4X,'GRAVITY',4X,'VOLUME',5X,
     *'VOLUME',7X,'GAS',/4X,'(PSIG)',4X,'(DEG.F)',4X,'(1)',6X,'(2)',4X,
     *'(DEG.API)',2X,'FACTOR(3)',2X,'FACTOR(4)',3X,'GRAVITY',/)
1230 FORMAT(4X,F5.1,6X,F4.0,5X,F5.0,4X,F5.0,27X,F5.3,6X,F5.3)
1240 FORMAT(4X,F5.1,6X,F4.0,5X,F5.0,4X,F5.0,5X,F4.1,7X,F5.3,6X,F5.3,
     *6X,F5.3)
1260 FORMAT(/3X,'NOTE',/3X,'----',/3X,'(1) GOR IN SCF/BBL',/3X,
     *'(2) GOR IN SCF/STB',/3X,'(3) BBLS OF OIL AT SATURATION PRESSURE
     *PER STB',/3X,'(4) BBLS OF OIL AT GIVEN P&T PER STB')
1315 FORMAT(1H1,/51X,29('*'),/51X,'*',1X,'DIFFERENTIAL VAPORIZATION',
     *1X,'*',/51X,29('*'))
1310 FORMAT(1H1,/55X,22('*'),/55X,'*',1X,'FLASH VAPORIZATION',1X,'*',
     */55X,22('*'))
      END
```

```
      SUBROUTINE ACEF
C
C     PURPOSE : ESTIMATE PROPERTIES OF HEAVY-PLUS USING
C               KESSLER-LEE CORRELATIONS.
C
C     INPUT PARAMETERS :
C       MWC7 = MOLECULAR WEIGHT OF HEAVY-PLUS (LB/LB-MOLE)
C       SGC7 = SPECIFIC GRAVITY OF HEAVY-PLUS (WATER=1)
C     OUTPUT PARAMETERS :
C       MVOL(16)= MOLAR VOLUME OF HEAVY-PLUS (CU.FT/LB-MOLE)
C       PC(16) = CRITICAL PRESSURE OF HEAVY-PLUS (PSIA)
C       TB(16) = NORMAL BOILING POINT TEMP. OF HEAVY-PLUS (DEG.R)
C       TC(16) = CRITICAL TEMP. OF HEAVY-PLUS (DEG.F)
C       W(16)  = ACENTRIC FACTOR OF HEAVY-PLUS
C     OTHER PARAMETERS :
C       KW  = WATSON CHARACTERIZATION FACTOR
C       TBR = REDUCED BOILING POINT TEMP.,TB/TC
C
      COMMON/D2/MW(16),MVOL(16)
      COMMON/D3/W(16),PC(16),TC(16)
      COMMON/D9/D(16,16),IBIN,TB(16)
      COMMON/D11/ID,MM
      COMMON/D13/GMWC7,SGGC7,MWC7,SGC7
      REAL KW,MWC7,MW,MVOL
      CHARACTER*1 M1
C     ESTIMATE NORMAL BOILING POINT TEMPERATURE.
      IT=1
      TBC=660.
   10 F=MWC7+12272.6-9486.4*SGC7-(4.6523-3.3287*SGC7)*TBC-(1.3437-1.0358
     **SGC7-.027653*SGC7**2)*1.E7/TBC+(720.79-555.6138*SGC7-14.83386
     **SGC7**2)*1.E7/(TBC**2)-(1.8828-1.52285*SGC7+.04191*SGC7**2)*1.E12
     */(TBC**3)+(181.98-147.1891*SGC7+4.05087*SGC7**2)*1.E12/(TBC**4)
      FP=-4.6523+3.3287*SGC7+(1.3437-1.0358*SGC7-.027653*SGC7**2)*1.E7
     */(TBC**2)-(1441.58-1111.23*SGC7-29.6677*SGC7**2)*1.E7/(TBC**3)+
     *(5.6484-4.5685*SGC7+.12573*SGC7**2)*1.E12/(TBC**4)-(727.92-588.756
     **SGC7+16.2035*SGC7**2)*1.E12/(TBC**5)
      IF (ABS(F).LT.1.E-3) GO TO 20
      TBC=TBC-F/FP
      IF (IT.GE.100) GO TO 50
      IT=IT+1
      GO TO 10
C     ESTIMATE CRITICAL TEMPERATURE AND PRESSURE.
   20 TCC=-118.3+811.*SGC7+(.4244+.1174*SGC7)*TBC+(.4669-3.2623*SGC7)
     **1.E5/TBC
      PC1=8.3634-.0566/SGC7-(.24244+2.2898/SGC7+.11857/(SGC7**2))*1.E-3
     **TBC+(1.4685+3.648/SGC7+.47227/(SGC7**2))*1.E-7*TBC**2-(.42019+
     *1.6977/(SGC7**2))*1.E-10*TBC**3
      PCC=EXP(PC1)
C     ESTIMATE ACENTRIC FACTOR.
      TBR=TBC/(TCC+460.)
```

```
      IF (TBR.GT.0.8) GO TO 30
      A1=ALOG(14.7/PCC)-5.92714+6.09648/TBR+1.28862*ALOG(TBR)-.169347
     **TBR**6
      A2=15.2518-15.6875/TBR-13.4721*ALOG(TBR)+.43577*TBR**6
      WC=A1/A2
      GO TO 40
   30 KW=TBC**(1./3.)/SGC7
      WC=-7.904+.1352*KW-.007465*KW**2+8.359*TBR+(1.408-.01063*KW)/TBR
   40 TBC=TBC-460.
      MW(16)=MWC7
      MVOL(16)=MWC7/(62.4*SGC7)
      WR16=(MWC7+28.2608)/347.826
      WRITE(7,100)
      WRITE(8,100)
      WRITE(7,120)TBC,TCC,PCC,WC
      WRITE(8,120)TBC,TCC,PCC,WC
      WRITE(7,130)WR16
   41 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'         ********************************************
     ******************'
      WRITE(*,*)'         *   DO YOU WANT TO USE DIFFERENT HEAVY-PLUS PA
     *RAMETERS ?     *'
      WRITE(*,*)'         *           (I.E. BOILING POINT, CRITICAL TEMP
     *ERATURE,            *'
      WRITE(*,*)'         *             CRITICAL PRESSURE, AND ACENTRIC
     *FACTOR)        *'
      WRITE(*,*)'         ********************************************
     ******************'
      WRITE(*,*)'                              *       (Y) YES       *'
      WRITE(*,*)'                              *                     *'
      WRITE(*,*)'                              *       (N) NO        *'
      WRITE(*,*)'                              ************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,'(A)')M1
      IF (M1.NE.'Y'.AND.M1.NE.'N') THEN
      IF (M1.NE.'y'.AND.M1.NE.'n') GO TO 41
      ENDIF
      IF (M1.EQ.'Y'.OR.M1.EQ.'y') GO TO 45
   43 TB(16)=TBC+460.
      TC(16)=TCC
      PC(16)=PCC
      W(16)=WC
      GO TO 60
   45 WRITE(*,*)
      WRITE(*,*)
```

```
      WRITE(*,*)
      WRITE(*,'(A\)')' HEAVY+ BOILING POINT -->'
      READ(*,*)TBA
      WRITE(*,'(A\)')' HEAVY+ CRITICAL TEMPERATURE -->'
      READ(*,*)TCA
      WRITE(*,'(A\)')' HEAVY+ CRITICAL PRESSURE -->'
      READ(*,*)PCA
      WRITE(*,'(A\)')' HEAVY+ ACENTRIC FACTOR -->'
      READ(*,*)WA
      TB(16)=TBA+460.
      TC(16)=TCA
      PC(16)=PCA
      W(16)=WA
      WRITE(7,160)
      WRITE(8,160)
      WRITE(7,120)TBA,TCA,PCA,WA
      WRITE(8,120)TBA,TCA,PCA,WA
      GO TO 60
   50 WRITE(7,110)
   60 RETURN

  100 FORMAT(//3X,'ESTIMATED PROPERTIES OF HEAVY-PLUS ARE :')
  120 FORMAT(/10X,'NORMAL BOILING POINT TEMP. = ',F7.2,2X,
     *'DEG.F',/10X,'CRITICAL TEMPERATURE = ',2X,F7.2,2X,'DEG.F',
     */10X,'CRITICAL PRESSURE    = ',2X,F7.2,2X,'PSIA',
     */10X,'ACENTRIC FACTOR      = ',2X,F6.4)
  110 FORMAT(/3X,'NO BOILING POINT TEMP. AVAILABLE FROM SUB.ACEF')
  130 FORMAT(/3X,'HEAVY-PLUS ACENTRIC FACTOR VALUE FROM MOL.WT.RELATIONS
     *HIP IS = ',1X,F8.6)
  160 FORMAT(/3X,'NEW HEAVY-PLUS PARAMETERS TO BE USED ARE :')
      END
```

```
      SUBROUTINE BINT
C
C     PURPOSE : ESTIMATE BINARY INTERACTION FACTORS.
C
C     INPUT PARAMETERS :
C       MW  = MOLECULAR WEIGHT (LB/LB-MOLE)
C       SOL = HILDEBRAND'S SOLUBILITY PARAMETER
C       TB  = NORMAL BOILING POINT TEMP. (DEG.R)
C     OUTPUT PARAMETERS :
C       D   = BINARY INTERACTION PARAMETER
C
      COMMON/D2/MW(16),MVOL(16)
      COMMON/D9/D(16,16),IBIN,TB(16)
      DIMENSION SOL(16)
      REAL MW
      DATA SOL/4.44,8.8,7.12,5.68,6.05,6.4,6.73,6.634,7.02,7.02,7.266,
     *7.43,7.551,7.649,7.722,7.55/
      D(1,1)=0.0
      D(1,2)=.14
      D(1,3)=.068
      D(2,1)=.14
      D(2,2)=0.0
      D(2,3)=.102
      D(3,1)=.068
      D(3,2)=.102
      D(3,3)=0.0
      D(1,16)=.16
      D(2,16)=.04
      D(3,16)=.1369
      D(16,1)=.16
      D(16,2)=.04
      D(16,3)=.1369
      IF (IBIN.GT.1) GO TO 21
C     ESTIMATE BINARY INTERACTION PARAMETERS OF CO2,N2 AND H2S
C     SYSTEM USING GRABOWSKI-DAUBERT CORRELATION.
C     N2-HYDROCARBON INTERACTION PARAMETERS.
      DO 10 I=4,15
           SOL1=ABS(SOL(I)-SOL(3))
           DUM1=.1294+.0292*SOL1-.0222*SOL1**2
           D(3,I)=DUM1
           D(I,3)=DUM1
   10 CONTINUE
C     CO2-HYDROCARBON INTERACTION PARAMETERS.
      DO 20 I=4,15
           SOL2=ABS(SOL(I)-SOL(1))
           DUM2=-.0836+.1055*SOL2-.01*SOL2**2
           D(1,I)=DUM2
           D(I,1)=DUM2
   20 CONTINUE
C     H2S-HYDROCARBON INTERACTION PARAMETERS.
```

```
   21 DO 30 I=4,15
            DUM3=.0178+.0244*ABS(SOL(I)-SOL(2))
            D(2,I)=DUM3
            D(I,2)=DUM3
   30 CONTINUE
C     ESTIMATE BINARY INTERACTION PARAMETERS USING LAVAL CORRELATION.
C     HYDROCARBON-HYDROCARBON BINARY INTERACTION PARAMETERS.
      DO 35 I=4,16
      DO 35 J=4,16
            DIFF=ABS(MW(I)-MW(J))
            IF (I.GT.J) GO TO 32
            TB1=TB(I)
            GO TO 33
   32       TB1=TB(J)
   33       DUM4=1.8*ALOG(DIFF+1.)**0.92/TB1
            D(I,J)=DUM4
   35 CONTINUE
      IF (IBIN.EQ.1) GO TO 60
C     N2-HYDROCARBONS BINARY INTERACTION PARAMETERS.
      DO 38 I=4,16
            DIFF1=ABS(MW(I)-MW(1))
            DUM5=1.8*ALOG(DIFF1+1.)**1.6/TB(1)
            D(I,1)=DUM5
            D(1,I)=DUM5
   38 CONTINUE
C     CO2-HYDROCARBONS BINARY INTERACTION PARAMETERS.
      DO 41 I=4,16
            DIFF2=ABS(MW(I)-MW(3))
            DUM6=1.8*ALOG(DIFF2+1.)**2.5/TB(3)
            D(I,3)=DUM6
            D(3,I)=DUM6
   41 CONTINUE
   60 RETURN

      END
```

```
      SUBROUTINE BUBPT
C
C     PURPOSE : CALCULATES BUBBLE POINT PRESSURE USING THE METHOD OF
C               SUMMATION OF Z1*K = 1.
C
C     INPUT PARAMETERS :
C       K  = EQUILIBRIUM RATIO
C       Z1 = COMPONENT GLOBAL MOLE FRACTION
C     OUTPUT PARAMETERS :
C       PB = BUBBLE POINT PRESSURE (PSIA)
C
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D8/PB,PBEXP
      REAL K
C     CALCULATES K-VALUE OF EACH COMPONENT.
      LB=1
    5 ITE=1
      CALL KCOR
    7 CALL FLASH
      CALL MOLES
      CALL EQR
      IF (ABS(SUMER).LT.1.E-5) GO TO 18
      IF (ITE.GE.100) GO TO 60
      ITE=ITE+1
      GO TO 7
   18 F=0.
C     CALCULATES SUMMATION OF Z1*K.
      DO 20 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 20
           F=F+Z1(I)*K(I)
   20 CONTINUE
      IF (LB.EQ.2) GO TO 30
      IF (F.GE.1.) GO TO 25
      GO TO 40
   25 P=P+100.
      GO TO 5
   30 IF (F.GE.1.) GO TO 50
   40 P=P-10.
      LB=2
      IF (P.GT.14.7) GO TO 5
      GO TO 65
   50 DO 58 INC=1,10
           P=P+1.
           IT1=1
           CALL KCOR
   53      CALL FLASH
           CALL MOLES
           CALL EQR
           IF (ABS(SUMER).LT.1.E-5) GO TO 55
```

```
      IF (IT1.GE.100) GO TO 60
      IT1=IT1+1
      GO TO 53
55    F=0.
      DO 56 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 56
           F=F+Z1(I)*K(I)
56    CONTINUE
      IF (F.LE.1.) GO TO 70
58 CONTINUE
   GO TO 63
60 WRITE(7,110)ITE
   WRITE(8,110)ITE
   GO TO 65
63 WRITE(7,120)P,F
   GO TO 70
65 P=0.
70 PB=P
   RETURN
110 FORMAT(1X,'K-VALUES DO NOT CONVERGE AFTER =',3X,I3,2X,'ITERATION')
120 FORMAT(/3X,'AT PRESSURE = ',3X,F8.2,2X,'PSIA',3X,'SUM OF Z.K = ',
  *3X,F8.6)
   END
```

```
      SUBROUTINE DENSL
C
C     PURPOSE : CALCULATE LIQUID MOLAR VOLUME AND DENSITY,AND GAS
C               SPECIFIC GRAVITY.
C
C     INPUT PARAMETERS :
C       MVOL = COMPONENT MOLAR VOLUME (CU.FT/LB-MOLE)
C       MW   = MOLECULAR WEIGHT (LB/LB-MOLE)
C       P    = PRESSURE (PSIA)
C       T    = TEMPERATURE (DEG.F)
C       Z2   = COMPONENT GLOBAL MOLE FRACTION
C       ZL   = LIQUID COMPRESSIBILITY FACTOR
C     OUTPUT PARAMETERS :
C       DENL = LIQUID DENSITY (LB/CU.FT)
C       SGG  = GAS SPECIFIC GRAVITY (AIR=1)
C       VL   = LIQUID MOLAR VOLUME (CU.FT/LB-MOLE)
C
      COMMON/D2/MW(16),MVOL(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D7/ZL,ZV
      COMMON/D14/VL,DENL,SGG,MLG,MS,Z2(16)
      REAL MVOL,MW,MWF
      DATA R/10.731/
      T1=T+460.
      MWF=0.
      VSC=0.
      DO 10 I=1,16
           IF (Z2(I).LT.1.E-25) GO TO 10
           MWF=MWF+Z2(I)*MW(I)
           VSC=VSC+Z2(I)*MVOL(I)
   10 CONTINUE
      IF (MLG.EQ.2) GO TO 30
      VL=ZL*R*T1/P
      DENL=MWF/VL
      IF (MS.EQ.1) GO TO 20
      GO TO 40
C     CALCULATE LIQUID DENSITY AT STANDARD CONDITIONS.
   20 VL=(VL+VSC)/2.
      DENL=MWF/VL
      GO TO 40
   30 SGG=MWF/28.97
   40 RETURN
      END
```

```
      SUBROUTINE DOUT
C
C     PURPOSE : PRINT OUTPUT DATA ON PHASE COMPOSITION.
C
C     OUTPUT PARAMETERS :
C       CN   = COMPONENT NAME
C       K    = EQUILIBRIUM RATIO
C       NG   = GAS MOLE FRACTION (FLASH VAP.)
C       NGD  = GAS MOLE FRACTION (DIFFERENTIAL VAP.)
C       NL   = LIQUID MOLE FRACTION (FLASH VAP.)
C       NLD  = LIQUID MOLE FRACTION (DIFFERENTIAL VAP.)
C       P    = PRESSURE (PSIA)
C       SUMX = SUM OF COMPONENT LIQUID MOLE FRACTIONS (FLASH VAP.)
C       SUMXD = SUM OF COMPONENT LIQUID MOLE FRACTIONS (DIFFERENTIAL
C               VAP.)
C       SUMY = SUM OF COMPONENT GAS MOLE FRACTIONS (FLASH VAP.)
C       SUMYD = SUM OF COMPONENT GAS MOLE FRACTIONS (DIFFERENTIAL
C               VAP.)
C       SUMZ = SUM OF COMPONENT GLOBAL MOLE FRACTIONS (FLASH VAP.)
C       SUMZD = SUM OF COMPONENT GLOBAL MOLE FRACTIONS (DIFFERENTIAL
C               VAP.)
C       X    = COMPONENT LIQUID MOLE FRACTION (FLASH VAP.)
C       XD   = COMPONENT LIQUID MOLE FRACTION (DIFFERENTIAL VAP.)
C       Y    = COMPONENT GAS MOLE FRACTION (FLASH VAP.)
C       YD   = COMPONENT GAS MOLE FRACTION (DIFFERENTIAL VAP.)
C       Z    = COMPONENT GLOBAL MOLE FRACTION (FLASH VAP.)
C       Z3   = COMPONENT GLOBAL MOLE FRACTION (DIFFERENTIAL VAP.)
C       ZL   = LIQUID COMPRESSIBILITY/DEVIATION FACTOR
C       ZV   = GAS COMPRESSIBILITY/DEVIATION FACTOR
C
      COMMON/D1/CN(16)
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D5/Z(16),X(16),Y(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D7/ZL,ZV
      COMMON/D10/NG,NL,SUMX,SUMY
      COMMON/D12/ISEP,NCOM,P1
      COMMON/D16/NGD,NLD,XD(16),YD(16),SUMXD,SUMYD,SUMZD
      CHARACTER*9 CN
      REAL K,NG,NL,NGD,NLD
      IF (ISEP.GT.1) GO TO 20
      WRITE(4,100)
      WRITE(4,110)P1,T,NG,NL
      WRITE(4,125)
      DO 16 I=1,16
           IF (Z(I).LT.1.E-25) GO TO 16
           WRITE(4,135)CN(I),Z(I),K(I),X(I),Y(I)
   16 CONTINUE
      WRITE(4,155)SUMZ,SUMX,SUMY
      WRITE(4,180)ZL,ZV
```

```
      GO TO 50
   20 WRITE(3,160)
      WRITE(3,110)P1,T,NGD,NLD
      WRITE(3,125)
      DO 45 I=1,16
           IF (Z3(I).LT.1.E-25) GO TO 45
           WRITE(3,135)CN(I),Z3(I),K(I),XD(I),YD(I)
   45 CONTINUE
      WRITE(3,155)SUMZD,SUMXD,SUMYD
      WRITE(3,180)ZL,ZV
   50 RETURN
  100 FORMAT(/3X,'FLASH SEPARATION CALCULATIONS.',/3X,'----------------
     *----------')
  110 FORMAT(/3X,'PRESSURE = ',3X,F6.1,2X,'PSIA',/3X,'TEMPERATURE = ',
     *3X,F6.1,2X,'DEG.F',/3X,'GAS MOLE FRACTION = ',3X,F6.4,/3X,
     *'LIQUID MOLE FRACTION = ',3X,F6.4)
  125 FORMAT(/18X,'TOTAL',5X,'EQUILIBRIUM',5X,'LIQUID',8X,'GAS',/3X,
     *'COMPONENT',2X,'COMPOSITION',2X,'RATIO(CAL)',3X,'COMPOSITION',
     *2X,'COMPOSITION')
  135 FORMAT(3X,A10,3X,F6.4,6X,F8.4,6X,F6.4,7X,F6.4)
  155 FORMAT(16X,F6.4,20X,F6.4,7X,F6.4)
  160 FORMAT(/3X,'DIFFERENTIAL VAPORIZATION CALCULATIONS.',/3X,'-------
     *-----------------------------------')
  180 FORMAT(3X,'Z-FACTOR',32X,F6.4,7X,F6.4)
      END
```

```
      SUBROUTINE DVAP
C
C     PURPOSE : CALCULATES LIQUID AND VAPOR MOLE FRACTIONS DUE TO
C               DIFFERENTIAL VAPORIZATION.
C
C     INPUT PARAMETERS :
C       K  = EQUILIBRIUM RATIO
C       Z3 = COMPONENT GLOBAL MOLE FRACTION
C     OUTPUT PARAMETERS :
C       NGD  = GAS MOLE FRACTION
C       NLD  = LIQUID MOLE FRACTION
C       SUMXD = SUM OF COMPONENT LIQUID MOLE FRACTIONS
C       SUMYD = SUM OF COMPONENT GAS MOLE FRACTIONS
C       SUMZD = SUM OF COMPONENT GLOBAL MOLE FRACTIONS
C       XD   = COMPONENT LIQUID MOLE FRACTION
C       YD   = COMPONENT GAS MOLE FRACTION
C
      REAL K,NGD,NLD
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D16/NGD,NLD,XD(16),YD(16),SUMXD,SUMYD,SUMZD
C     CALCULATE LIQUID AND VAPOR MOLE FRACTIONS.
      IT1=1
      NLD=0.5
   10 F=0.
      FPRIME=0.
      DO 20 I=1,16
      IF (Z3(I).LT.1.E-25) GO TO 20
           F=F+Z3(I)*(NLD**(K(I)-1.))*(K(I)-1.)
           FPRIME=FPRIME+Z3(I)*(NLD**(K(I)-2.))*((K(I)-1.)**2)
   20 CONTINUE
      IF (ABS(F).LT.1.E-4) GO TO 30
      NLD=NLD-F/FPRIME
      IF (NLD.LE.0.) GO TO 40
      IT1=IT1+1
      IF (IT1.GT.50) GO TO 80
      GO TO 10
   30 IF (NLD.GT.1.) GO TO 60
C     CALCULATES LIQUID AND VAPOR MOLE FRACTIONS OF EACH COMPONENT.
      SUMXD=0.
      SUMYD=0.
      SUMZD=0.
      DO 35 I=1,16
           IF (Z3(I).LT.1.E-25) GO TO 32
           XD(I)=Z3(I)*NLD**(K(I)-1.)
           YD(I)=XD(I)*K(I)
           SUMXD=SUMXD+XD(I)
           SUMYD=SUMYD+YD(I)
           SUMZD=SUMZD+Z3(I)
           GO TO 35
   32      XD(I)=0.
```

```
      YD(I)=0.
35 CONTINUE
   NGO=1.-NLD
   GO TO 90
40 NLD=0.
   NGO=1.
   SUMXD=0.
   SUMYD=0.
   DO 50 I=1,16
      XD(I)=0.
      YD(I)=Z3(I)
      SUMYD=SUMYD+YD(I)
50 CONTINUE
   SUMZD=SUMYD
   GO TO 90
60 NLD=1.
   NGO=0.
   SUMXD=0.
   SUMYD=0.
   DO 70 I=1,16
      XD(I)=Z3(I)
      YD(I)=0.
      SUMXD=SUMXD+XD(I)
70 CONTINUE
   SUMZD=SUMXD
   GO TO 90
80 WRITE(7,100)
90 RETURN
100 FORMAT(//3X,'NO CONVERGENCE IN SUBROUTINE DVAP.')
   END
```

```
      SUBROUTINE DATA1
C
C     PURPOSE : INTERPRET INPUT INFORMATION.
C
      COMMON/D1/CN(16)
      COMMON/D2/MW(16),MVOL(16)
      COMMON/D3/W(16),PC(16),TC(16)
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D5/Z(16),X(16),Y(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D12/ISEP,NCOM,P1
      COMMON/D13/GMWC7,SGGC7,MWC7,SGC7
      COMMON/D16/NGD,NLD,XD(16),YD(16),SUMXD,SUMYD,SUMZD
      COMMON/D20/INPUTW,GOR,IOUT,FLSH,DIFF,OUTPUT,PSEP(5),TSEP(5)
      COMMON/D21/IPRINT
      REAL K,MWC7,MW,MVOL
      CHARACTER*1 IPRINT
      CHARACTER*9 CN
      CHARACTER*14 INFILE,FLSH,DIFF,OUTPUT
      IF (INPUTW.EQ.1) GO TO 30
      IF (INPUTW.EQ.2) GO TO 73
      GO TO 97
C     SEPARATOR OUTPUT COMPOSITION GIVEN - RECOMBINATION REQUIRED.
   30 IF (X(16).LT.1.E-25.AND.Y(16).LT.1.E-25) GO TO 50
      CALL ACEF
   50 SUM1=0.
      DO 55 I=1,16
          SUM1=SUM1+X(I)*MVOL(I)
   55 CONTINUE
      CUML=1./SUM1
      CUMG=GOR/379.4
      CUMGL=CUMG+CUML
C     STORES GLOBAL MOLE FRACTION IN Z1.
      DO 60 I=1,16
          Z1(I)=(X(I)*CUML+Y(I)*CUMG)/CUMGL
   60 CONTINUE
      DO 65 J=1,16
          IF (Z1(J).GT.0.) GO TO 70
   65 CONTINUE
   70 SUMZ=0.
      DO 72 I=J+1,16
          SUMZ=SUMZ+Z1(I)
   72 CONTINUE
      Z1(J)=1.-SUMZ
      IF (Z1(16).LT.1.E-25) GO TO 95
      GO TO 95
C     WELL STREAM COMPOSITION IS GIVEN.
   73 SUMZ=0.
      DO 80 I=1,16
          SUMZ=SUMZ+Z1(I)
```

```
 80 CONTINUE
    IF (Z1(16).LT.1.E-25) GO TO 95
    CALL ACEF
 95 P=PR
    T=TR
    GO TO 98
 97 WRITE(7,220)
 98 RETURN
220 FORMAT(/3X,'INPUT ERROR.')
    END
```

```
      SUBROUTINE EQR
C
C     PURPOSE : CALCULATE EQUILIBRIUM RATIO OF EACH COMPONENT USING
C               THE PENG-ROBINSON EQUATION OF STATE.
C
C     INPUT PARAMETERS :
C       D  = BINARY INTERACTION FACTOR
C       P  = PRESSURE (PSIA)
C       T  = TEMPERATURE (DEG.F)
C       TC = CRITICAL TEMPERATURE (DEG.F)
C       W  = ACENTRIC FACTOR
C       X  = COMPONENT LIQUID MOLE FRACTION
C       Y  = COMPONENT GAS MOLE FRACTION
C       ZL = LIQUID COMPRESSIBILITY/DEVIATION FACTOR
C       ZV = GAS COMPRESSIBILITY/DEVIATION FACTOR
C     OUTPUT PARAMETERS :
C       K  = EQUILIBRIUM RATIO
C     OTHER PARAMETERS :
C       FRAT = FUGACITY RATIO (IN ACC. SUCCESSIVE SUBSTITUTION)
C       FUGR = FUGACITY RATIO (IN SUCCESSIVE SUBSTIUTTION)
C       LAMDA = ACCELERATION FACTOR
C       OLDFR = PREVIOUS FUGACITY RATIO
C     FLAG :
C       IKV = 2 INDICATES EQUILIBRIUM RATIOS ARE CALCULATED BY
C       USING THE P-R EQUATION OF STATE
C
      COMMON/D3/W(16),PC(16),TC(16)
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D5/Z(16),X(16),Y(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D7/ZL,ZV
      COMMON/D9/D(16,16),IBIN,TB(16)
      COMMON/D15/IKV,METH
      DIMENSION A(16),B(16),TC1(16),XA(16),YA(16),FRAT(16),OLDFR(16),
     *PK(16)
      REAL K,LAMDA
      DATA R/10.731/
      DATA ERROR/1.E-5/
      T1=T+460.
      DO 20 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 10
           TC1(I)=TC(I)+460.
           TRED=T1/TC1(I)
           A1=.37464+1.54226*W(I)-.26992*W(I)**2
           A2=1.+A1*(1.-SQRT(TRED))
           A3=.45724*(R**2)*(TC1(I)**2)/PC(I)
           A(I)=A3*(A2**2)
           B(I)=.0778*R*TC1(I)/PC(I)
           GO TO 20
   10      A(I)=0.
```

```
          B(I)=0.
   20 CONTINUE
C     CALCULATE Z-FACTOR OF LIQUID PHASE.
      ASL=0.
      BSL=0.
      DO 40 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 35
           BSL=BSL+X(I)*B(I)
           XL=0.
           DO 30 J=1,16
                IF (Z1(J).LT.1.E-25) GO TO 30
                AIJ=(1.-D(I,J))*(SQRT(A(I)*A(J)))
                ASL=ASL+X(I)*X(J)*AIJ
                XL=XL+X(J)*AIJ
   30      CONTINUE
           XA(I)=XL
           GO TO 40
   35      XA(I)=0.
   40 CONTINUE
      AL=ASL*P/((R*T1)**2)
      BL=BSL*P/(R*T1)
      CALL QROOT(AL,BL,ZL,1)
C     CALCULATE Z-FACTOR OF VAPOR PHASE.
      ASV=0.
      BSV=0.
      DO 60 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 55
           BSV=BSV+Y(I)*B(I)
           YV=0.
           DO 50 J=1,16
                IF (Z1(J).LT.1.E-25) GO TO 50
                AIJ=(1.-D(I,J))*SQRT(A(I)*A(J))
                ASV=ASV+Y(I)*Y(J)*AIJ
                YV=YV+Y(J)*AIJ
   50      CONTINUE
           YA(I)=YV
           GO TO 60
   55      YA(I)=0.
   60 CONTINUE
      AV=ASV*P/(R*T1)**2
      BV=BSV*P/(R*T1)
      CALL QROOT(AV,BV,ZV,2)
      IF ((ASL.LT.1.E-25).OR.(ASV.LT.1.E-25)) GO TO 61
      GO TO 59
   61 SUMER=0.
      GO TO 95
C     CALCULATE COMPONENT FUGACITY COEFFICIENTS AND K-VALUES.
   59 CONS1=(ZL-1.)/BSL-(ZV-1.)/BSV
      CONS2=ALOG((ZV-BV)/(ZL-BL))
      CONS3=(AL/(SQRT(8.)*BL))*ALOG((ZL+(SQRT(2.)+1.)*BL)/(ZL-(SQRT(2.)
```

```
     *     -1.)*BL))
           CONSV=(AV/(SQRT(8.)*BV))*ALOG((ZV+(SQRT(2.)+1.)*BV)/(ZV-(SQRT(2.)
     *     -1.)*BV))
           IF (METH.GT.1) GO TO 81
C          ESTIMATE K-VALUES USING SUCCESSIVE SUBSTITUTION METHOD.
           SUMER=0
           DO 80 I=1,16
                IF (Z1(I).LT.1.E-25) GO TO 65
                FUGR=ALOG(X(I)/Y(I))+B(I)*CONS1+CONS2-CONSL*(2.*XA(I)/ASL-
     *               B(I)/BSL)+CONSV*(2.*YA(I)/ASV-B(I)/BSV)
                PK(I)=K(I)
                K(I)=PK(I)*EXP(FUGR)
                DIF=K(I)-PK(I)
                PROD=K(I)*PK(I)
                IF (PROD.LT.1.E-20) PROD=1.E-20
                SUMER=SUMER+DIF*DIF/PROD
                GO TO 80
65              K(I)=0.
80         CONTINUE
           GO TO 95
C          ESTIMATE K-VALUES USING ACCELERATED SUCCESSIVE SUBSTITUTION
C          METHOD.
81         SUMFR1=0.
           SUMFR2=0.
           SUMER=0.
           RMAX=0.
           IF (IKV.EQ.2) GO TO 75
           DO 72 I=1,16
                OLDFR(I)=1.0
72         CONTINUE
75         DO 82 I=1,16
                IF (Z1(I).LT.1.E-25) GO TO 82
                FRAT(I)=ALOG(X(I)/Y(I))+B(I)*CONS1+CONS2-CONSL*(2.*XA(I)/ASL
     *               -B(I)/BSL)+CONSV*(2.*YA(I)/ASV-B(I)/BSV)
                SUMFR1=SUMFR1+OLDFR(I)**2
                SUMFR2=SUMFR2+OLDFR(I)*FRAT(I)
                RMAX=AMAX1(RMAX,ABS(FRAT(I)))
                OLDFR(I)=FRAT(I)
82         CONTINUE
           IF (IKV.EQ.1) GO TO 83
           DIF=ABS(SUMFR1-SUMFR2)
           IF (DIF.GT.(ERROR**2*SUMFR2)) GO TO 84
83         LAMDA=1.0
           GO TO 86
84         LAMDA=SUMFR1/DIF*LAMDA
           RLIM=LAMDA*RMAX
           IF (RLIM.GT.6.) LAMDA=6./RMAX
86         DO 88 I=1,16
                IF (Z1(I).LT.1.E-25) GO TO 87
                PK(I)=K(I)
```

```
      K(I)=PK(I)*EXP(LAMDA*FRAT(I))
      DIF=K(I)-PK(I)
      PROD=K(I)*PK(I)
      IF (PROD.LT.1.E-20) PROD=1.E-20
      SUMER=SUMER+DIF*DIF/PROD
      GO TO 88
87    K(I)=0.
88 CONTINUE
95 IKV=2
   RETURN
   END
```

```
      SUBROUTINE FLASH
C
C     PURPOSE : CALCULATE PHASE MOLE FRACTIONS DUE TO FLASH
C               VAPORIZATION.
C
C     INPUT PARAMETERS :
C       K  = EQUILIBRIUM RATIO
C       Z1 = GLOBAL MOLE FRACTION
C     OUTPUT PARAMETERS :
C       NG = GAS MOLE FRACTION
C       NL = LIQUID MOLE FRACTION
C
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D10/NG,NL,SUMX,SUMY
      COMMON/D15/IKV,METH
      EXTERNAL FX
      REAL K,NG,NL
C     CALCULATE PHASE MOLE FRACTIONS USING COMBINED BISECTION/SECANT/
C     INVERSE QUADRATIC INTERPOLATION METHOD.
      A=1.E-10
      B=1.0
      TOL=1.E-10
      NG=ZEROIN(A,B,FX,TOL)
      NL=1.-NG
      RETURN
      END
```

```
      REAL FUNCTION FX(X)
C
C     INPUT PARAMETERS :
C       K  = EQUILIBRIUM RATIO
C       Z1 = COMPONENT GLOBAL MOLE FRACTION
C     OUTPUT PARAMETER :
C       FX = FUNCTION USED IN FLASH VAPORIZATION
C
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      REAL K
      F=0.0
      DO 10 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 10
           DIFF=K(I)-1.
           F=F+Z1(I)*DIFF/(1.+X*DIFF)
   10 CONTINUE
      FX=F
      RETURN
      END
```

```
      REAL FUNCTION ZEROIN(AX,BX,FX,TOL)
C
C     PURPOSE : COMPUTE A ROOT OF FUNCTION FX(X) IN THE INTERVAL
C               AX,BX
C
C     INPUT PARAMETERS:
C       AX  = LEFT ENDPOINT OF INITIAL INTERVAL
C       BX  = RIGHT ENDPOINT OF INITIAL INTERVAL
C       FX  = FUNCTION SUBPROGRAM WHICH EVALUATES FX(X) FOR ANY
C             X IN THE INTERVAL AX,BX
C       TOL = DESIRED TOLERANCE (1.E-10)
C
C     OUTPUT PARAMETER:
C       ZEROIN = COMPUTED ROOT OF FUNCTION FX(X)
C
C     COMPUTE EPS,THE RELATIVE MACHINE PRECISION.
C
      EPS=1.0
   10 EPS=EPS/2.0
      TOL1=1.0+EPS
      IF (TOL1.GT.1.0) GO TO 10
C     INITIALIZATION.
      A=AX
      B=BX
      FA=FX(A)
      FB=FX(B)
C     BEGIN STEP
   20 C=A
      FC=FA
      D=B-A
      E=D
   30 IF (ABS(FC).GE.ABS(FB)) GO TO 40
      A=B
      B=C
      C=A
      FA=FB
      FB=FC
      FC=FA
C     CONVERGENCE TEST.
   40 TOL1=2.0*EPS*ABS(B)+0.5*TOL
      XM=0.5*(C-B)
      IF (ABS(XM).LE.TOL1) GO TO 90
      IF (FB.EQ.0.0) GO TO 90
C     IS BISECTION NECESSARY.
      IF (ABS(E).LT.TOL1) GO TO 70
      IF (ABS(FA).LE.ABS(FB)) GO TO 70
C     IS QUADRATIC INTERPOLATION POSSIBLE.
      IF (A.NE.C) GO TO 50
C     LINEAR INTERPOLATION (SECANT METHOD).
      S=FB/FA
```

```
      P=2.0*XM*S
      Q=1.0-S
      GO TO 60
C     INVERSE QUADRATIC FUNCTION.
   50 Q=FA/FC
      R=FB/FC
      S=FB/FA
      P=S*(2.0*XM*(Q-R)-(B-A)*(R-1.0))
      Q=(Q-1.0)*(R-1.0)*(S-1.0)
C     ADJUST SIGNS.
   60 IF (P.GT.0.0) Q=-Q
      P=ABS(P)
C     IS INTERPOLATION ACCEPTABLE.
      IF ((2.0*P).GE.(3.0*XM*Q-ABS(TOL1*Q))) GO TO 70
      IF (P.GE.ABS(0.5*E*Q)) GO TO 70
      E=D
      D=P/Q
      GO TO 80
C     BISECTION.
   70 D=XM
      E=D
C     COMPLETE STEP.
   80 A=B
      FA=FB
      IF (ABS(D).GT.TOL1) B=B+D
      IF (ABS(D).LE.TOL1) B=B+SIGN(TOL1,XM)
      FB=FX(B)
      IF ((FB*(FC/ABS(FC))).GT.0.0) GO TO 20
      GO TO 30
C     DONE
   90 ZEROIN=B
      RETURN
      END
```

```
      SUBROUTINE KCOR
C
C     PURPOSE : ESTIMATE INITIAL SET OF EQUILIBRIUM RATIOS USING
C               CORRELATION.
C
C     INPUT PARAMETERS :
C       P   = PRESSURE (PSIA)
C       PC  = CRITICAL PRESSURE (PSIA)
C       T   = TEMPERATURE (DEG.F)
C       TC  = CRITICAL TEMPERATURE (DEG.F)
C       W   = ACENTRIC FACTOR
C     OUTPUT PARAMETERS :
C       K   = EQUILIBRIUM RATIO
C     FLAG :
C       IKV = 1 INDICATES EQUILIBRIUM RATIOS ARE ESTIMATED FROM
C       CORRELATION.
C
      COMMON/D3/W(16),PC(16),TC(16)
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D15/IKV,METH
      DIMENSION TC1(16)
      REAL K
      IKV=1
      T1=T+460.
      DO 20 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 10
           TC1(I)=TC(I)+460.
           K(I)=EXP(5.37*(1.+W(I))*(1.-TC1(I)/T1))/(P/PC(I))
           GO TO 20
   10      K(I)=0.
           TC1(I)=0.
   20 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MOLES
C
C     PURPOSE : CALCULATE COMPONENT PHASE MOLE FRACTIONS.
C
C     INPUT PARAMETERS :
C       K    = EQUILIBRIUM RATIO
C       NG   = GAS MOLE FRACTION
C       NL   = LIQUID MOLE FRACTION
C       Z1   = COMPONENT GLOBAL MOLE FRACTION
C     OUTPUT PARAMETERS :
C       SUMX = SUM OF COMPONENT LIQUID MOLE FRACTIONS
C       SUMY = SUM OF COMPONENT GAS MOLE FRACTIONS
C       SUMZ = SUM OF COMPONENT GLOBAL MOLE FRACTIONS
C       X    = COMPONENT LIQUID MOLE FRACTION
C       Y    = COMPONENT GAS MOLE FRACTION
C
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D5/Z(16),X(16),Y(16)
      COMMON/D10/NG,NL,SUMX,SUMY
      REAL K,NG,NL
C     CALCULATE COMPONENT MOLE FRACTIONS.
      SUMX=0.
      SUMY=0.
      IF ((1.-NL).LT.1.E-4) GO TO 60
      IF (NL.LT.1.E-4) GO TO 70
      IF (NL.GT.NG) GO TO 55
      DO 50 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 40
           X(I)=Z1(I)/(K(I)+NL*(1.-K(I)))
           Y(I)=K(I)*X(I)
           SUMX=SUMX+X(I)
           SUMY=SUMY+Y(I)
           GO TO 50
   40      X(I)=0.
           Y(I)=0.
   50 CONTINUE
      GO TO 90
   55 DO 58 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 56
           X(I)=Z1(I)/(1.+NG*(K(I)-1.))
           Y(I)=K(I)*X(I)
           SUMX=SUMX+X(I)
           SUMY=SUMY+Y(I)
           GO TO 58
   56      X(I)=0.
           Y(I)=0.
   58 CONTINUE
      GO TO 90
   60 NL=1.
      NG=0.
```

```
      DO 65 I=1,16
           X(I)=Z1(I)
           Y(I)=0.
           SUMX=SUMX+X(I)
   65 CONTINUE
      GO TO 90
   70 NL=0.
      NG=1.
      DO 75 I=1,16
           X(I)=0.
           Y(I)=Z1(I)
           SUMY=SUMY+Y(I)
   75 CONTINUE
   90 RETURN
      END
```

```
      SUBROUTINE PHASEB
C
C     PURPOSE : IDENTIFY TYPE OF FLUID SYSTEM USING SUMMATION OF
C               Z*K AND Z/K.
C
C     INPUT PARAMETERS :
C       K  = EQUILIBRIUM RATIO
C       P  = PRESSURE (PSIA)
C       Z1 = GLOBAL COMPONENT MOLE FRACTION
C     OUTPUT PARAMETERS :
C       ID = TYPE OF FLUID SYSTEM; ID=1 INDICATES BLACK/VOLATILE
C            OIL SYSTEM, AND ID=3 INDICATES RETROGRADE CONDENSATE
C            SYSTEM. ID=2 INDICATES TWO-PHASE FLUID BEHAVIOR.
C
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D11/ID,MM
      REAL K
C     CALCULATE K-VALUES AT GIVEN PRESSURE & TEMPERATURE.
      ID=4
      P=PR
   10 ITE=1
      CALL KCOR
   15 CALL FLASH
      CALL MOLES
      CALL EQR
      IF (ABS(SUMER).LT.1.E-5) GO TO 20
      IF (ITE.GE.100) GO TO 16
      ITE=ITE+1
      GO TO 15
   16 WRITE(7,190)
      WRITE(8,190)
      ID=0
      GO TO 80
C     CHECK FOR PHASE BEHAVIOR OF FLUID.
   20 SUMKZ1=0.
      SUMKZ2=0.
      DO 30 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 30
           SUMKZ1=SUMKZ1+Z1(I)*K(I)
           SUMKZ2=SUMKZ2+Z1(I)/K(I)
   30 CONTINUE
      IF (ABS(SUMKZ1-1.0).LT.1.E-4) GO TO 40
      IF (ABS(SUMKZ2-1.0).LT.1.E-4) GO TO 45
      IF ((SUMKZ1.GT.1.0).AND.(SUMKZ2.GT.1.0)) GO TO 50
      IF ((SUMKZ1.LT.1.0).AND.(SUMKZ2.LT.1.0)) GO TO 55
      IF (SUMKZ1.LT.1.0) GO TO 60
      IF (ID.EQ.2) GO TO 47
      GO TO 47
   40 IF (ID.EQ.2) GO TO 65
```

```
      GO TO 65
   45 IF (ID.EQ.2) GO TO 47
   47 ID=3
      GO TO 70
   50 IF (ID.EQ.2) GO TO 70
      ID=2
      GO TO 70
   55 CONTINUE
      ID=0
      GO TO 70
   60 IF (ID.EQ.2) GO TO 65
   65 ID=1
   70 CONTINUE
      IF (ID.NE.2) GO TO 80
      P=P+100.
      GO TO 10
   80 RETURN

  190 FORMAT(/3X,'NO CONVERGENCE IN SUB. PHASEB AFTER 100 ITERATIONS.')
      END
```

```
      SUBROUTINE QROOT(A,B,ROOT,L)
C
C     PURPOSE : CALCULATE THE REAL ROOTS OF THE PENG-ROBINSON CUBIC
C               EQUATION OF STATE IN Z-FACTOR.
C
C     INPUT PARAMETERS :
C       A,B = PARAMETERS OBTAINED FROM THE PENG-ROBINSON
C                   EQUATION OF STATE.
C     OUTPUT PARAMETERS :
C       ROOT = LIQUID OR GAS COMPRESSIBILITY/DEVIATION FACTOR
C     FLAG :
C       L = 1 INDICATES LIQUID PHASE.
C       L = 2 INDICATES GAS PHASE.
C
      C1=B*(B*B+B-A)
      C2=A-B*(B*3.+2.)
      C3=B-1.
      B1=(3.*C2-C3*C3)/3.
      B0=(2.*(C3**3)-9.*C2*C3+27.*C1)/27.
      DET=(B1/3.)**3+(B0/2.)**2
      IF (DET.LT.0.) GO TO 10
      IF (DET.LT.1.E-20) GO TO 20
      L1=1
      GO TO 20
   10 IF (B1.GT.0.) GO TO 95
      PHI=ACOS((-B0/2.)*(-3./B1)**1.5)
      PI=2.*ASIN(1.0)
      B2=2.*SQRT(-B1/3.)
      Y1=B2*COS(PHI/3.)-C3/3.
      Y2=B2*COS(PHI/3.+2.*PI/3.)-C3/3.
      Y3=B2*COS(PHI/3.+4.*PI/3.)-C3/3.
      IF (L.EQ.1) GO TO 15
      ROOT=AMAX1(Y1,Y2,Y3)
      GO TO 90
   15 IF (Y1.LE.0.) Y1=1.E6
      IF (Y2.LE.0.) Y2=1.E6
      IF (Y3.LE.0.) Y3=1.E6
      ROOT=AMIN1(Y1,Y2,Y3)
      IF (ROOT.GT.1.E5) GO TO 95
      GO TO 90
   20 DET1=SQRT(DET)
      F1=-B0/2.+DET1
      F2=-B0/2.-DET1
      IF (F1.LT.0.0.AND.F2.LT.0.0) GO TO 30
      IF (F1.LT.0.0.AND.F2.GT.0.0) GO TO 40
      IF (F1.GT.0.0.AND.F2.LT.0.0) GO TO 50
      Y1=F1**(1./3.)+F2**(1./3.)-C3/3.
      GO TO 60
   30 F1=-F1
      F2=-F2
```

```
      Y1=-(F1**(1./3.)+F2**(1./3.))-C3/3.
      GO TO 60
   40 F1=-F1
      Y1=-(F1**(1./3.))+F2**(1./3.)-C3/3.
      GO TO 60
   50 F2=-F2
      Y1=F1**(1./3.)-(F2**(1./3.))-C3/3.
   60 IF (L1.EQ.1) GO TO 70
      F4=-B0/2.
      IF (F4.LT.0.) THEN
         F4=-F4
         Y2=-(F4**(1./3.))-C3/3.
      ELSE
         Y2=F4**(1./3.)-C3/3.
      ENDIF
      IF (L.EQ.1) GO TO 65
      ROOT=AMAX1(Y1,Y2)
      GO TO 90
   65 IF (Y1.LE.0.0.AND.Y2.LE.0.) GO TO 95
      IF (Y1.LE.0.) THEN
         ROOT=Y2
      ELSE
         ROOT=Y1
      ENDIF
      GO TO 90
   70 ROOT=Y1
      GO TO 90
   95 WRITE(7,100)
      WRITE(8,100)
   90 L1=2
      RETURN
  100 FORMAT(/3X,'NO ROOTS AVAILABLE IN SUB.QROOT.')
      END
```

```
      SUBROUTINE VISCG(PRES,T2,GG,Z,VGAS)
C
C     PURPOSE : CALCULATE GAS VISCOSITY USING LEE-EAKIN CORRELATION.
C
C     INPUT PARAMETERS :
C       GG   = GAS SPECIFIC GRAVITY (AIR=1)
C       PRES = PRESSURE (PSIA)
C       T2   = TEMPERATURE (DEG.F)
C       Z    = GAS COMPRESSIBILITY/DEVIATION FACTOR
C     OUTPUT PARAMETERS :
C       VGAS = GAS VISCOSITY (CP)
C
      REAL K
      IF (Z.LE.0.) GO TO 10
      TEMP=T2+460.
      K=(9.4+.58*GG)*(TEMP**1.5)/(209.+551.*GG+TEMP)
      X=3.5+986./TEMP+.2897*GG
      G=2.4-.2*X
      DENS=.043264*GG*PRES/(Z*TEMP)
      VGAS=K*EXP(X*DENS**G)/10000.
      GO TO 20
   10 VGAS=0.
   20 RETURN
      END
```

```
      SUBROUTINE VISCL(DEN,TEMP,RS,VISL,M)
C
C     PURPOSE : CALCULATE LIQUID VISCOSITY USING BEGGS-ROBINSON
C               CORRELATION.
C
C     INPUT PARAMETERS :
C       DEN  = LIQUID DENSITY AT STANDARD CONDITIONS (LB/CU.FT)
C       RS   = SOLUTION GAS-OIL RATIO (SCF/STB)
C       TEMP = TEMPERATURE (DEG.F)
C       M    = NO. OF PRESSURE STAGES
C     OUTPUT PARAMETERS :
C       VISL = VISCOSITY OF LIQUID (CP)
C
      DIMENSION RS(M),VISL(M)
      DOAPI=141.5*62.4/DEN-131.5
      R1=3.0324-0.02023*DOAPI
      R2=10.**R1
      R3=R2*(TEMP**(-1.163))
      VISD=(10.**R3)-1.
      DO 10 I=1,M
           R4=10.715*((RS(I)+100.)**(-0.515))
           R5=5.44*((RS(I)+150.)**(-0.338))
           VISL(I)=R4*(VISD**R5)
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INPUT
C
C     PURPOSE : READS INPUT DATA
C
      COMMON/D1/CN(16)
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ,Z3(16)
      COMMON/D5/Z(16),X(16),Y(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D8/PB,PBEXP
      COMMON/D9/D(16,16),IBIN,TB(16)
      COMMON/D13/GMWC7,SGGC7,MWC7,SGC7
      COMMON/D15/IKV,METH
      COMMON/D20/INPUTH,GOR,IOUT,FLSH,DIFF,OUTPUT,PSEP(5),TSEP(5)
      COMMON/D21/IPRINT
      COMMON/D22/NS
      CHARACTER*14 INFILE,FLSH,DIFF,OUTPUT
      CHARACTER*9 CN
      CHARACTER*1 RESP,IPRINT
      REAL MWC7
      DO 1 I=1,16
        X(I)=1.
        Y(I)=1.
        Z1(I)=1.
    1 CONTINUE
      WRITE(*,*)'              ***VOLATILE OIL PVT ANALYSIS***'
    2 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'          ****************************************'
      WRITE(*,*)'          *  (1) INPUT DATA FOR CALCULATION    *'
      WRITE(*,*)'          *                OR                  *'
      WRITE(*,*)'          *  (2) RETRIEVE DATA INPUT FILE      *'
      WRITE(*,*)'          ****************************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,*)INPUT
      IF (INPUT.LT.1.OR.INPUT.GT.2) GO TO 2
      IF (INPUT.EQ.2) THEN
      WRITE(*,'(A\)')' NAME OF INPUT FILE TO BE RETRIEVED ? -->'
      READ(*,'(A)')INFILE
      OPEN(9,FILE=INFILE,STATUS='OLD')
      READ(9,*)INPUTH,(X(I),Y(I),Z1(I),I=1,16),MWC7,SGC7,GMWC7,SGGC7,
     *GOR,PR,TR,PBEXP,METH,IBIN,IOUT
      READ(9,'(4A)')FLSH,DIFF,OUTPUT,IPRINT
      READ(9,*)NS
      IF (NS.LT.0.OR.NS.GT.5) GO TO 35
      IF (NS.GT.0) THEN
      READ(9,*)(PSEP(I),TSEP(I),I=1,NS)
```

```
      ENDIF
      IF (INPUTW.EQ.1.OR.INPUTW.EQ.2) GO TO 12
   35 WRITE(*,'(A)')' BAD INPUT FILE'
      GO TO 2
      ENDIF
    3 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'                    ************************'
      WRITE(*,*)'                    *     SAMPLE TYPE      *'
      WRITE(*,*)'                    ************************'
      WRITE(*,*)'                    *  (1) RECOMBINATION   *'
      WRITE(*,*)'                    *        OR            *'
      WRITE(*,*)'                    *  (2) WELL-STREAM     *'
      WRITE(*,*)'                    ************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,*)INPUTW
      IF (INPUTW.LT.1.OR.INPUTW.GT.2) GO TO 3
      IF (INPUTW.EQ.2) GO TO 5
      WRITE(*,'(A)')' INPUT MOLE FRACTIONS FOR THE FOLLOWING COMPONENTS'
      WRITE(*,'(A)')' (LIQUID FRACTION,VAPOR FRACTION)'
      DO 4 I=1,16
        WRITE(*,'(A,A9,A\)')' ',CN(I),'  -->'
        READ(*,*)X(I),Y(I)
    4 CONTINUE
      GO TO 7
    5 WRITE(*,'(A)')' INPUT MOLE FRACTIONS FOR THE FOLLOWING COMPONENTS'
      DO 6 I=1,16
        WRITE(*,'(A,A9,A\)')' ',CN(I),'  -->'
        READ(*,*)Z1(I)
    6 CONTINUE
    7 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A)')' ENTER THE FOLLOWING PARAMETERS'
      WRITE(*,*)
      WRITE(*,'(A\)')' MOLECULAR WEIGHT OF THE LIQUID PHASE HEAVY+ -->'
      READ(*,*)XMWC7
      WRITE(*,'(A\)')' SPECIFIC GRAVITY OF THE LIQUID PHASE HEAVY+ -->'
      READ(*,*)SGC7
      WRITE(*,'(A)')' MOLECULAR WEIGHT OF THE VAPOR PHASE HEAVY+'
      WRITE(*,'(A)')' IF NOT AVAILABLE, TYPE 0.'
      WRITE(*,'(A\)')' -->'
      READ(*,*)GMWC7
      WRITE(*,'(A)')' SPECIFIC GRAVITY OF THE VAPOR PHASE HEAVY+'
      WRITE(*,'(A)')' IF NOT AVAILABLE, TYPE 0.'
      WRITE(*,'(A\)')' -->'
```

```
      READ(*,*)SGGC7
      WRITE(*,*)
      WRITE(*,'(A)')' SYSTEM GAS-OIL RATIO (SCF/STB)'
      WRITE(*,'(A)')' FOR WELL-STREAM SAMPLE, TYPE 0.'
      WRITE(*,'(A\)')' -->'
      READ(*,*)GOR
      WRITE(*,'(A\)')' SYSTEM PRESSURE (PSIA) -->'
      READ(*,*)PR
      WRITE(*,'(A\)')' SYSTEM TEMPERATURE (DEG.F) -->'
      READ(*,*)TR
      WRITE(*,'(A)')' EXPERIMENTAL BUBBLE POINT (PSIA)'
      WRITE(*,'(A)')' IF NOT AVAILABLE, TYPE 0.'
      WRITE(*,'(A\)')' -->'
      READ(*,*)PBEXP
   30 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'            **********************************'
      WRITE(*,*)'            *   DO YOU WANT MULTI-STAGE      *'
      WRITE(*,*)'            *   SEPARATION CALCULATIONS ?    *'
      WRITE(*,*)'            **********************************'
      WRITE(*,*)'            *   (0) NO                       *'
      WRITE(*,*)'            *   (1) YES, 1 STAGE             *'
      WRITE(*,*)'            *   (2) YES, 2 STAGES            *'
      WRITE(*,*)'            *   (3) YES, 3 STAGES            *'
      WRITE(*,*)'            *   (4) YES, 4 STAGES            *'
      WRITE(*,*)'            *   (5) YES, 5 STAGES            *'
      WRITE(*,*)'            **********************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,*)NS
      IF(NS.LT.0.OR.NS.GT.5.) GO TO 30
      IF(NS.GT.0) THEN
      WRITE(*,*)
      WRITE(*,*)' ENTER SEPARATOR PRESSURE (PSIA),TEMPERATURE (DEG.F)'
      WRITE(*,*)
      DO 31 I=1,NS
       WRITE(*,'(A,I1,A\)')' STAGE ',I,' -->'
       READ(*,*)PSEP(I),TSEP(I)
   31 CONTINUE
      ENDIF
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') GO TO 24
    8 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'      ************************************************'
      WRITE(*,*)'      *    EQUILIBRIUM RATIO ESTIMATION              *'
      WRITE(*,*)'      ************************************************'
```

```
      WRITE(*,*)'      *    (1) SUCCESSIVE SUBSTITUTION              *'
      WRITE(*,*)'      *                  OR                         *'
      WRITE(*,*)'      *    (2) ACCELERATED SUCCESSIVE SUBSTITUTION  *'
      WRITE(*,*)'      ********************************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,*)METH
      IF (METH.LT.1.OR.METH.GT.2) GO TO 8
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') GO TO 24
    9 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'          ******************************************'
      WRITE(*,*)'          *   ESTIMATION OF HC-N2 AND HC-CO2       *'
      WRITE(*,*)'          *   BINARY INTERACTION PARAMETERS        *'
      WRITE(*,*)'          ******************************************'
      WRITE(*,*)'          *   (1) GRABOWSKI-DAUBERT CORRELATION    *'
      WRITE(*,*)'          *                 OR                     *'
      WRITE(*,*)'          *   (2) LAVAL CORRELATION                *'
      WRITE(*,*)'          ******************************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,*)IBIN
      IF (IBIN.LT.1.OR.IBIN.GT.2) GO TO 9
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') GO TO 24
   10 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'          ******************************************'
      WRITE(*,*)'          *   DO YOU WANT PHASE COMPOSITION FILES ?  *'
      WRITE(*,*)'          ******************************************'
      WRITE(*,*)'          *                (Y) YES                   *'
      WRITE(*,*)'          *                                          *'
      WRITE(*,*)'          *                (N) NO                    *'
      WRITE(*,*)'          ******************************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,'(A)')IPRINT
      IF (IPRINT.NE.'Y'.AND.IPRINT.NE.'N') THEN
      IF (IPRINT.NE.'y'.AND.IPRINT.NE.'n') GO TO 10
      ENDIF
      IF (IPRINT.EQ.'Y'.OR.IPRINT.EQ.'y') THEN
      WRITE(*,*)
      WRITE(*,*)
```

```
      WRITE(*,*)
      WRITE(*,*)'     ***INPUT FILE NAME (USING PC-DOS STANDARD)***'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' NAME OF FILE FOR FLASH PHASE COMPOSITIONS -->'
      READ(*,'(A)')FLSH
      WRITE(*,'(A\)')' NAME OF FILE FOR DIFFERENTIAL PHASE COMPOSITIONS
     *-->'
      READ(*,'(A)')DIFF
      ELSE
      FLSH='NO FILE'
      DIFF='NO FILE'
      ENDIF
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') GO TO 24
   11 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'          ************************'
      WRITE(*,*)'          *       OUTPUT         *'
      WRITE(*,*)'          ************************'
      WRITE(*,*)'          *   (1) TO PRINTER     *'
      WRITE(*,*)'          *         OR           *'
      WRITE(*,*)'          *   (2) TO FILE        *'
      WRITE(*,*)'          ************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,*)IOUT
      IF (IOUT.LT.1.OR.IOUT.GT.2) GO TO 11
      IF (IOUT.EQ.2) THEN
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'     ***INPUT FILE NAME (USING PC-DOS STANDARD)***'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' NAME OF FILE FOR OUTPUT -->'
      READ(*,'(A)')OUTPUT
      ELSE
      OUTPUT='PRN'
      ENDIF
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') GO TO 24
   12 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A)')' ***SUMMARY OF COMPONENT MOLE FRACTION***'
      WRITE(*,*)
      IF (INPUTW.EQ.2) GO TO 14
      WRITE(*,'(A)')'     COMPONENT     LIQUID MOLE   VAPOR MOLE'
```

```
      WRITE(*,'(A)')'                          FRACTION      FRACTION'
      DO 13 I=1,16
        WRITE(*,'(A,I2,2X,A9,6X,F8.6,6X,F8.6)')' ',I,CN(I),X(I),Y(I)
   13 CONTINUE
      WRITE(*,*)
      WRITE(*,'(A\)')' DO YOU WANT TO CHANGE ANY COMPONENT MOLE FRACTION
     * (Y OR N) ? -->'
      READ(*,'(A)')RESP
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') THEN
      WRITE(*,'(A\)')' ENTER LINE NUMBER OF COMPONENT TO BE CHANGED -->'
      READ(*,*)INT
      WRITE(*,'(A)')' ENTER (LIQUID FRACTION, VAPOR FRACTION)'
      WRITE(*,'(A,A,A\)')' ',CN(INT),'  -->'
      READ(*,*)X(INT),Y(INT)
      GO TO 12
      ELSE
      GO TO 16
      ENDIF
   14 WRITE(*,'(A)')'     COMPONENT    MOLE FRACTION'
      DO 15 I=1,16
        WRITE(*,'(A,I2,2X,A9,6X,F8.6)')' ',I,CN(I),Z1(I)
   15 CONTINUE
      WRITE(*,*)
      WRITE(*,'(A\)')' DO YOU WANT TO CHANGE ANY COMPONENT MOLE FRACTION
     * (Y OR N) ? -->'
      READ(*,'(A)')RESP
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') THEN
      WRITE(*,'(A\)')' ENTER LINE NUMBER OF COMPONENT TO BE CHANGED -->'
      READ(*,*)INT
      WRITE(*,'(A)')' ENTER NEW MOLE FRACTION'
      WRITE(*,'(A,A,A\)')' ',CN(INT),'  -->'
      READ(*,*)Z1(INT)
      GO TO 12
      ENDIF
   16 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A)')' ***SUMMARY OF INPUT PARAMETERS***'
      WRITE(*,*)
      WRITE(*,'(A,F8.3)')' (1) MOLECULAR WEIGHT OF LIQUID HEAVY+
     *= ',MWC7
      WRITE(*,'(A,F8.6)')' (2) SPECIFIC GRAVITY OF LIQUID HEAVY+
     *= ',SGC7
      WRITE(*,'(A,F8.3)')' (3) MOLECULAR WEIGHT OF VAPOR HEAVY+
     *= ',GMWC7
      WRITE(*,'(A,F8.6)')' (4) SPECIFIC GRAVITY OF VAPOR HEAVY+
     *= ',SGGC7
      WRITE(*,'(A,F8.6)')' (5) SYSTEM GAS-OIL RATIO (SCF/STB)
     *= ',GOR
      WRITE(*,'(A,F8.2)')' (6) SYSTEM PRESSURE (PSIA)
```

```
     *= ',PR
      WRITE(*,'(A,F8.2)')' (7) SYSTEM TEMPERATURE (DEG.F)
     *= ',TR
      WRITE(*,'(A,F8.2)')' (8) EXPERIMENTAL BUBBLE POINT PRESSURE (PSIA)
     *= ',PBEXP
      WRITE(*,*)
      WRITE(*,'(A\)')' DO YOU WANT TO CHANGE ANY INPUT PARAMETERS (Y OR
     *N) ? -->'
      READ(*,'(A)')RESP
      IF(RESP.EQ.'Y'.OR.RESP.EQ.'y') THEN
      WRITE(*,'(A\)')' ENTER LINE NUMBER OF PARAMETER TO BE CHANGED -->'
      READ(*,*)INT
      GOTO(17,18,19,20,40,21,22,23)INT
   17 WRITE(*,'(A\)')' MOLECULAR WEIGHT OF LIQUID HEAVY+ -->'
      READ(*,*)MWC7
      GO TO 16
   18 WRITE(*,'(A\)')' SPECIFIC GRAVITY OF LIQUID HEAVY+ -->'
      READ(*,*)SGC7
      GO TO 16
   19 WRITE(*,'(A\)')' MOLECULAR WEIGHT OF VAPOR HEAVY+ -->'
      READ(*,*)GMWC7
      GO TO 16
   20 WRITE(*,'(A\)')' SPECIFIC GRAVITY OF VAPOR HEAVY+ -->'
      READ(*,*)SGGC7
      GO TO 16
   40 WRITE(*,'(A\)')' SYSTEM GAS-OIL RATIO (SCF/STB) -->'
      READ(*,*)GOR
      GO TO 16
   21 WRITE(*,'(A\)')' SYSTEM PRESSURE (PSIA) -->'
      READ(*,*)PR
      GO TO 16
   22 WRITE(*,'(A\)')' SYSTEM TEMPERATURE (DEG.F) -->'
      READ(*,*)TR
      GO TO 16
   23 WRITE(*,'(A\)')' EXPERIMENTAL BUBBLE POINT PRESSURE (PSIA) -->'
      READ(*,*)PBEXP
      GO TO 16
      ENDIF
   24 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)' ***SUMMARY OF COMPUTATIONAL PARAMETERS***'
      WRITE(*,*)
      WRITE(*,'(A,I1,A)')'  [1]   MULTI-STAGE SEPARATION CALCULATIONS:
     *',NS,' STAGE'
      IF(NS.GT.0) THEN
      WRITE(*,*)'       PRESSURE   TEMPERATURE'
      DO 33 I=1,NS
      WRITE(*,'(9X,F6.1,7X,F5.1)')PSEP(I),TSEP(I)
   33 CONTINUE
```

```
      ENDIF
      WRITE(*,*)
      WRITE(*,'(A,I1)')  [2]   EQUILIBRIUM RATIO ESTIMATION:-->',METH
      WRITE(*,*)'        (1) SUCCESSIVE SUBSTITUTION'
      WRITE(*,*)'        (2) ACCELERATED SUCCESSIVE SUBSTITUTION'
      WRITE(*,*)
      WRITE(*,*)' [3]   ESTIMATION OF HC-N2 AND HC-CO2       '
      WRITE(*,'(A,I1)')'        BINARY INTERACTION PARAMETERS:-->',IBIN
      WRITE(*,*)'        (1) GRABOWSKI-DAUBERT CORRELATION    '
      WRITE(*,*)'        (2) LAWAL CORRELATION                '
      WRITE(*,*)
      WRITE(*,*)' [4]   PHASE COMPOSITION FILES'
      WRITE(*,'(A,A)')'        FLASH PHASE COMPOSITION:-->',FLSH
      WRITE(*,'(A,A)')'        DIFFERENTIAL PHASE COMPOSITION:-->',DIFF
      WRITE(*,*)
      IF (IOUT.EQ.1) THEN
      WRITE(*,'(A)')'  [5]   OUTPUT:-->PRINTER'
      ELSE
      WRITE(*,'(A,A)')'  [5]   OUTPUT:-->',OUTPUT
      ENDIF
      WRITE(*,*)
      WRITE(*,'(A\)')' DO YOU WANT TO CHANGE ANY COMPUTATIONAL PARAMETER
     *S (Y OR N) ? -->'
      READ(*,'(A)')RESP
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') THEN
      WRITE(*,'(A\)')' ENTER LINE NUMBER OF PARAMETER TO BE CHANGED -->'
      READ(*,*)INT
      GOTO(30,8,9,10,11)INT
      ENDIF
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)' ************************************************************
     ********'
      WRITE(*,*)' ************************************************************
     ********'
      WRITE(*,*)' **   DO YOU WANT TO SAVE INPUT DATA IN A FILE (Y OR N)
     * ?   **'
      WRITE(*,*)' ************************************************************
     ********'
      WRITE(*,*)' ************************************************************
     ********'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,'(A)')RESP
```

```
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') THEN
      WRITE(*,'(A\)')' NAME OF INPUT FILE (USING PC-DOS STANDARD) -->'
      READ(*,'(A)')INFILE
      OPEN(9,FILE=INFILE,STATUS='NEW')
      WRITE(9,*)INPUTW,(X(I),Y(I),Z1(I),I=1,16),MWC7,SGC7,GMWC7,
     *SGGC7,GOR,PR,TR,PBEXP,METH,IBIN,IOUT
      WRITE(9,'(4A)')XFLSH,DIFF,OUTPUT,IPRINT
      WRITE(9,*)NS
      IF (NS.GT.0) THEN
      WRITE(9,*)(PSEP(I),TSEP(I),I=1,NS)
      ENDIF
      ENDIF
      CLOSE (9)
      RETURN
      END
```

```
      SUBROUTINE EXDATA
C
C     PURPOSE : STORE DATA FOR PVT ANLYSIS AND FOR EXAMPLE CALCULATIONS.
C
      COMMON/D1/CN(16)
      COMMON/D2/MW(16),MVOL(16)
      COMMON/D3/W(16),PC(16),TC(16)
      COMMON/D9/D(16,16),IBIN,TB(16)
      REAL MVOL,MW
      CHARACTER*9 CN
      CN(1)='N2'
      CN(2)='H2S'
      CN(3)='CO2'
      CN(4)='METHANE'
      CN(5)='ETHANE'
      CN(6)='PROPANE'
      CN(7)='I-BUTANE'
      CN(8)='N-BUTANE'
      CN(9)='I-PENTANE'
      CN(10)='N-PENTANE'
      CN(11)='HEXANES'
      CN(12)='HEPTANES'
      CN(13)='OCTANES'
      CN(14)='NONANES'
      CN(15)='DECANES'
      CN(16)='HEAVY+'
      MW(1)=28.013
      MW(2)=34.076
      MW(3)=44.01
      MW(4)=16.043
      MW(5)=30.07
      MW(6)=44.097
      MW(7)=58.124
      MW(8)=58.124
      MW(9)=72.151
      MW(10)=72.151
      MW(11)=86.178
      MW(12)=100.125
      MW(13)=114.232
      MW(14)=128.259
      MW(15)=142.286
      MW(16)=0.0
      MVOL(1)=.5561
      MVOL(2)=.8529
      MVOL(3)=.6911
      MVOL(4)=.8555
      MVOL(5)=1.3528
      MVOL(6)=1.3929
      MVOL(7)=1.655
      MVOL(8)=1.5948
```

```
MVOL(9)=1.8515
MVOL(10)=1.8328
MVOL(11)=2.0814
MVOL(12)=2.3341
MVOL(13)=2.5921
MVOL(14)=2.85
MVOL(15)=3.1067
MVOL(16)=0.0
W(1)=.04
W(2)=.1
W(3)=.225
W(4)=.0104
W(5)=.0986
W(6)=.1524
W(7)=.1848
W(8)=.201
W(9)=.2223
W(10)=.2539
W(11)=.3007
W(12)=.3498
W(13)=.3942
W(14)=.4455
W(15)=.4885
W(16)=.375
PC(1)=493.024
PC(2)=1306.17
PC(3)=1071.17
PC(4)=667.8
PC(5)=707.8
PC(6)=616.3
PC(7)=529.1
PC(8)=550.7
PC(9)=490.4
PC(10)=488.6
PC(11)=436.9
PC(12)=396.8
PC(13)=360.6
PC(14)=332.
PC(15)=304.
PC(16)=396.8
TC(1)=-232.424
TC(2)=212.717
TC(3)=87.923
TC(4)=-116.63
TC(5)=90.09
TC(6)=206.01
TC(7)=274.98
TC(8)=305.65
TC(9)=369.1
TC(10)=385.7
```

```
TC(11)=453.7
TC(12)=512.8
TC(13)=564.22
TC(14)=610.68
TC(15)=652.1
TC(16)=512.8
TB(1)=139.27
TB(2)=383.066
TB(3)=350.37
TB(4)=201.
TB(5)=332.21
TB(6)=416.02
TB(7)=470.59
TB(8)=490.79
TB(9)=541.81
TB(10)=556.61
TB(11)=615.41
TB(12)=668.86
TB(13)=717.91
TB(14)=763.16
TB(15)=805.17
TB(16)=0.0
END
```

APPENDIX C

PVTGC Program Listing

```
C     THOMAS TUFTS
C     PETROLEUM ENGINEERING DEPT.
C
C     PROGRAM PVTGC(INPUT,OUTPUT,TTY,FLSH,TAPE5=TTY,TAPE6=OUTPUT,
C    *TAPE4=FLSH)
C
C     PURPOSE : TO COMPUTE PVT PROPERTIES OF A GAS CONDENSATE WHICH
C               ARE NORMALLY DETERMINED IN THE LABORATORY.
C
C     INPUT DATA : A MINIMUM INPUT OF DATA ARE REQUIRED,NAMELY-
C                  1. RESERVOIR PRESSURE
C                  2. RESERVOIR TEMPERATURE
C                  3. FLUID COMPOSITION
C
C     INPUT PARAMETERS :
C       ALL OUTPUT PARAMETERS FROM SUBROUTINES ACEF,BINT,DATA1,DATA2,
C       DENSL,DEWCOR,DEWPT,EQR,FLASH,KCOR,MOLES,PHASEB,QROOT,
C       AND VISCG,INCLUDING FROM BLOCK DATA.
C
C     OUTPUT PARAMETERS :
C       BG   = GAS FORMATION VOLUME FACTOR AT EACH PRESSURE STAGE
C              (CU.FT/SCF)
C       BO   = RELATIVE OIL VOLUME AT EACH PRESSURE STAGE (BBL/STB)
C       BT   = TOTAL FORMATION VOLUME FACTOR AT EACH PRESSURE STAGE
C              (BBL/STB)
C       CGP  = CUMULATIVE GAS PHASE PRODUCED (MSCF)
C       CGP1 = % GAS PHASE PRODUCED (% VOL)
C       DEN  = LIQUID DENSITY AT EACH PRESSURE STAGE (LB/CU.FT)
C       ELCE = EQUIVALENT LIQUID CONTENT IN GAS PHASE-ETHANE (GPM)
C       ELCP = EQUIVALENT LIQUID CONTENT IN GAS PHASE-PROPANE (GPM)
C       ELCB = EQUIVALENT LIQUID CONTENT IN GAS PHASE-BUTANES (GPM)
C       ELCPE = EQUIVALENT LIQUID CONTENT IN GAS PHASE-PENTANE PLUS
C              (GPM)
C       FVF  = RATIO OF OIL VOLUME AT SATURATION TO OIL VOLUME AT
C              STANDARD CONDITIONS (BBL/STB)
C       GOR1 = RATIO OF VOLUME OF GAS AT 14.7 PSIA AND 60 DEG.F TO
C              VOLUME OF OIL AT GIVEN PRESSURE AND TEMPERATURE
C              (SCF/BBL)
C       GOR2 = RATIO OF VOLUME OF GAS AT 14.7 PSIA AND 60 DEG.F TO
C              VOLUME OF OIL AT 14.7 PSIA AND 60 DEG.F
C       NG   = GAS MOLE FRACTION AT EACH FLASH VAP. STAGE
C       NL   = LIQUID MOLE FRACTION AT EACH FLASH VAP. STAGE
C       PDC  = UPPER DEW POINT PRESSURE CALCULATED FROM NEMETH-
C              KENNEDY CORRELATION (PSIA)
C       PDEXP = EXPERIMENTAL UPPER DEW POINT PRESSURE (PSIA)
C       PD1  = CALCULATED UPPER DEW POINT PRESSURE (PSIA)
C       PD2  = CALCULATED LOWER DEW POINT PRESSURE (PSIA)
C       P    = PRESSURE (PSIA)
C       PP   = PRESSURE AT EACH DIFFERENTIAL OR FLASH VAP. STAGE
```

```
C                (PSIA)
C          PP2  = PLANT PRODUCT-ETHANE (GAL)
C          PP3  = PLANT PRODUCT-PROPANE (GAL)
C          PP4  = PLANT PRODUCT-BUTANES (GAL)
C          PP5  = PLANT PRODUCT-PENTANE PLUS (GAL)
C          PSEP = SEPARATOR PRESSURE (PSIG)
C          RV   = RELATIVE VOLUME, I.E. RATIO OF FLUID VOLUME AT GIVEN
C                 PRESSURE STAGE TO FLUID VOLUME AT SATURATION
C          SGG1 = GAS SPECIFIC GRAVITY AT EACH PRESSURE STAGE (AIR=1)
C          SGGS = GAS SPECIFIC GRAVITY DURING MULTI-STAGE SEPARATION
C                 (AIR=1)
C          SNL  = LIQUID MOLE FRACTION AT EACH SEPARATOR STAGE
C          SVF  = SEPARATOR OIL VOLUME FACTOR (BBL/STB)
C          TOAPI = TANK OIL API GRAVITY AT 60 DEG.F
C          TSEP = SEPARATOR TEMPERATURE (DEG.F)
C          VISG1 = GAS VISCOSITY AT EACH PRESSURE STAGE (CP)
C          VLS  = LIQUID MOLAR VOLUME AT EACH SEPARATOR STAGE
C                 (CU.FT/LB-MOLE)
C          ZV1  = GAS COMPRESSIBILITY/DEVIATION FACTOR AT EACH
C                 PRESSURE STAGE
C
C     OTHER PARAMETERS :
C          DIF  = DIFFERENCE BETWEEN CALCULATED AND EXPERIMENTAL DEW
C                 POINT PRESSURE (PSIA)
C          FLR  = LIQUID MOLE FRACTION REMAINING AT FINAL FLASH VAP.
C                 STAGE
C          FLS  = LIQUID MOLE FRACTION AT EACH FLASH VAP. STAGE
C          IT1,IT2,ETC = NO. OF ITERATIONS
C          V    = LIQUID MOLAR VOLUME AT EACH PRESSURE STAGE
C                 (CU.FT/LB-MOLE)
C          VGF1 = GAS VOLUME AT EACH FLASH VAP. STAGE (CU.FT)
C          Z2   = COMPONENT MOLE FRACTION
C          Z3   = COMPONENT MOLE FRACTION
C          Z4   = COMPONENT MOLE FRACTION
C
C     FLAG :
C          ID    = TYPE OF FLUID SYSTEM. ID=1 INDICATES BLACK/VOLATILE
C                  OIL; ID=3 INDICATES RETROGRADE CONDENSATE SYSTEM.
C          IBIN  = CHOICE OF CORRELATION USED TO ESTIMATE BINARY
C                  INTERACTION PARAMETERS (BIP). IBIN=1 INDICATES
C                  USE OF GRABOWSKI-DAUBERT CORRELATION FOR H/C-CO2
C                  AND H/C-N2 BIP. IBIN=2 INDICATES THE USE OF LAWAL'S
C                  CORRELATION FOR SIMILAR BIP.
C          IDEW  = DEW POINT PRESSURE CALCULATIONS. IDEW=1 INDICATES
C                  UPPER DEW POINT AND IDEW=2 INDICATES LOWER DEW POINT.
C          IPRINT = INDICATES WHETHER OUTPUT ON FLUID COMPOSITION IS
C                  FILED OR NOT. IPRINT=Y INDICATES THE OUTPUT IS
C                  FILED WHERERS IPRINT=N INDICATES NO FILES.
C          METH  = METHOD USED IN EQUILIBRIUM RATIO ESTIMATION.
C                  METH=1 INDICATES USE OF SUCCESSIVE SUBSTITUTION AND
```

```
C               METH>1 INDICATES USE OF ACCELERATED SUCCESSIVE
C               SUBSTITUTION
C       MLG   = CALCULATIONS USED IN SUB. DENSL. MLG=1 INDICATES
C               CALC. OF LIQUID MOLAR VOLUME AND DENSITY. MLG=2
C               INDICATES CALC. OF GAS SPECIFIC GRAVITY
C       MS    = TEMPERATURE AND PRESSURE CONDITIONS. MS=0 INDICATES
C               CONDITIONS AT GIVEN P & T. MS=1 INDICATES STANDARD
C               CONDITIONS (14.7 PSIA & 60 DEG.F). MS=2 INDICATES
C               CONDITIONS AT 14.7 PSIA & GIVEN TEMP.
C     SUBROUTINE REFERENCE : RCEF,DATA1,DATA2,DENSL,DEWPT,DOUT,EQR,
C                            FLASH,KCOR,MOLES,PHASEB,QROOT,VISCG
C
      COMMON/D1/CN(16)
      COMMON/D2/MW(16),MVOL(16)
      COMMON/D3/W(16),PC(16),TC(16)
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ
      COMMON/D5/Z(16),X(16),Y(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D7/ZL,ZV
      COMMON/D11/ID,MM
      COMMON/D9/D(16,16),IBIN,TB(16)
      COMMON/D10/NG,NL,SUMX,SUMY
      COMMON/D8/PD,PDC,PDEXP
      COMMON/D12/NCOM
      COMMON/D13/MWC7,SGC7,GMWC7,SGGC7
      COMMON/D14/VL,DENL,SGG,MLG,MS,Z2(16)
      COMMON/D15/IKV,METH
      COMMON/D17/IDEW
      COMMON/D20/INPUTW,GOR,IOUT,FLSH,DIFF,OUTPUT,PSEP(5),TSEP(5)
      COMMON/D21/IPRINT
      COMMON/D22/NS
      DIMENSION BG(100),DEN(100),SGG1(100),TMGS(100),VK(100),VISG1(100),
     *X1(16),Y1(16),Z5(16),Z4(16),ZV1(100),CGP(100),ELCE(100),
     *ELCP(100),ELCB(100),ELCPE(100),DIF(20),
     *SNL(10),VLS(10),SGGS(10),GOR1(10),GOR2(10),SUF(10)
      REAL K,NG,NGC,NL,MW,MWC7,MVOL
      CHARACTER*1 IPRINT
      CHARACTER*9 CN
      CHARACTER*14 FLSH,DIFF,OUTPUT
      OPEN (5,FILE='CON')
      CALL EXDATA
      CALL INPUT
      OPEN (6,FILE=OUTPUT,STATUS='NEW')
      IF (IPRINT.EQ.'Y'.OR.IPRINT.EQ.'y') THEN
       OPEN (4,FILE='FLSH',STATUS='NEW')
      ENDIF
C     SELECT ITERATIVE METHOD OF ESTIMATING K-VALUES.
    4 WRITE(5,1011)
      WRITE(6,1011)
      WRITE(6,1012)
```

```
      SUM2=0.
      CALL DATA1
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'            ****************************'
      WRITE(*,*)'            *** PROGRAM IN PROGRESS ***'
      WRITE(*,*)'            ***    PLEASE WAIT.      ***'
      WRITE(*,*)'            ****************************'
      WRITE(*,*)'            ****** 5-30 MINUTES ********'
      WRITE(*,*)'            ****************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      IF (METH.EQ.1) THEN
        WRITE(6,1015)
      ELSE
        WRITE(6,1016)
      ENDIF
      IF (IBIN.EQ.1) THEN
        WRITE(6,1017)
      ELSE
        WRITE(6,1018)
      ENDIF
   10 CALL BINT
C     READ EXPERIMENTAL FIRST DEW POINT PRESSURE.
   11 WRITE(5,1031)TR,PR
      WRITE(6,1031)TR,PR
      IF (PDEXP.LT.1.0) THEN
        WRITE(5,1032)
        WRITE(6,1032)
      ELSE
        WRITE(5,1033)PDEXP
        WRITE(6,1033)PDEXP
      ENDIF
      WRITE(5,1034)
      WRITE(6,1034)
      DO 12 I=1,16
          IF (Z1(I).LT.1.E-25) GO TO 12
              WRITE(5,1035)CN(I),Z1(I)
              WRITE(6,1035)CN(I),Z1(I)
   12 CONTINUE
      IF (Z1(16).LT.1.E-25) GO TO 20
      WRITE(5,1024)MWC7,SGC7
      WRITE(6,1024)MWC7,SGC7
      CALL DEWCOR
      WRITE(5,1010)PDC
      WRITE(6,1010)PDC
      P=PR
   20 IF (PDEXP.GT.1.) GO TO 25
```

```
C     IDENTIFY TYPE OF FLUID.
      CALL PHASEB
      IF (ID.LT.2) THEN
        WRITE(*,*)
        WRITE(*,*)
        WRITE(*,*)
        WRITE(*,*)' ************************************************'
        WRITE(*,*)' *** SYSTEM PRESSURE OUT OF TWO-PHASE RANGE  ***'
        WRITE(*,*)' *** PROGRAM WILL RESELECT A SYSTEM PRESSURE ***'
        WRITE(*,*)' *** IN TWO-PHASE REGION TO PERMIT FLASHING  ***'
        WRITE(*,*)' ************************************************'
        WRITE(*,*)
        WRITE(*,*)
        WRITE(*,*)
      ENDIF
C     CALCULATE FIRST DEW POINT PRESSURE (NEMETH-KENNEDY CORRELATION).
C     CALCULATE FIRST DEW POINT PRESSURE.
   25 IDEW=1
      P=.9*PDC
      CALL DEWPT
      IF (PDEXP.LT.1.) GO TO 35
      PDIF=PDEXP-PD
      IF ((ABS(PDIF).LE.25.).OR.(Z1(16).LT.1.E-25)) GO TO 35
      DMIN=0.1
      DO 33 I=1,10
           IF (I.EQ.1) GO TO 31
           D(4,16)=D(4,16)+0.02
           D(16,4)=D(16,4)+0.02
           CALL DEWPT
   31      DIF(I)=PD-PDEXP
           IF (I.EQ.1) GO TO 32
           IF (DIF(I).GT.0) GO TO 34
           IF (ABS(DIF(I)).GE.ABS(DMIN)) GO TO 34
   32      DMIN=DIF(I)
           BIN=D(4,16)
           WRITE(5,1026)BIN,DMIN,PD
   33 CONTINUE
   34 D(4,16)=BIN
      D(16,4)=BIN
      PD=PDEXP+DMIN
   35 PD1=PD
      WRITE(5,1030)PD1
      WRITE(6,1030)PD1
C     CALCULATE SECOND DEW POINT PRESSURE.
      P=PD1/2.
      IDEW=2
      CALL DEWPT
      PD2=PD
      WRITE(5,1036)PD2
      WRITE(6,1036)PD2
```

```
   37 MS=0
      TMG=0.
      TML=0.
      P=PD1
      DO 40 I=1,16
           Z5(I)=Z1(I)
           Z4(I)=Z1(I)
           X(I)=Z1(I)
   40 CONTINUE
C     PERFORM CONSTANT VOLUME DEPLETION CALCULATIONS.
      DO 120 IT=1,50
C          FLASH SEPARATION OF VAPOR.
           IT1=1
           CALL KCOR
   55      CALL FLASH
           CALL MOLES
           CALL EQR
           IF (ABS(SUMER).LT.1.E-5) GO TO 70
           IF (IT1.GE.100) GO TO 65
           IT1=IT1+1
           GO TO 55
   65      WRITE(5,1050)IT1
           WRITE(6,1050)IT1
   70      NGC=NG
           ZF=ZV
           SY=SUMY
           DO 80 I=1,16
                X1(I)=X(I)
                Y1(I)=Y(I)
                Z(I)=Z1(I)
   80      CONTINUE
           IF (IPRINT.GT.1) GO TO 82
           WRITE(6,1037)
           CALL DOUT
   82      IF (IT.GT.2) GO TO 90
           DO 85 I=1,16
                Z1(I)=Y(I)
                Z2(I)=X(I)
                Z5(I)=X(I)
   85      CONTINUE
           NG=0.
           GO TO 105
C          FLASH SEPARATION OF LIQUID.
   90      DO 91 I=1,16
                Z1(I)=Z5(I)
                Z(I)=Z5(I)
   91      CONTINUE
           IT3=1
           CALL KCOR
   92      CALL FLASH
```

```
            CALL MOLES
            CALL EQR
            IF (ABS(SUMER).LT.1.E-5) GO TO 97
            IF (IT3.GE.100) GO TO 96
            IT3=IT3+1
            GO TO 92
   96       WRITE(5,1050)IT3
            WRITE(6,1050)IT3
            GO TO 300
   97       IF (IPRINT.GT.1) GO TO 99
            WRITE(6,1038)
            CALL DOUT
   99       DO 100 I=1,16
                 Z1(I)=(NGC*Y1(I)+NG*Y(I))/(NGC+NG)
                 Z5(I)=((1.-NGC)*X1(I)+(1.-NG)*X(I))/(2.-NGC-NG)
                 Z2(I)=Z5(I)
  100       CONTINUE
  105       ZV=ZF
            SUMY=SY
C           CALCULATE LIQUID MOLAR VOLUME AND DENSITY.
            MLG=1
            CALL DENSL
            DEN(IT)=DENL/62.4
            TML=TMG*(1.-NGC)+TML*(1.-NG)
            V(IT)=VL*TML
            DO 110 I=1,16
                 Z2(I)=Z1(I)
  110       CONTINUE
C           CALCULATE GAS SPECIFIC GRAVITY AND VISCOSITY.
            MLG=2
            CALL DENSL
            ZV1(IT)=ZV
            SGG1(IT)=SGG
            CALL VISCG(P,T,SGG,ZV,VISG)
            VISG1(IT)=VISG
C           BRING GAS TO ORIGINAL VOLUME.
            TMG=(100.-V(IT))*P/(10.731*ZV1(IT)*(T+460.))
            TMGS(IT)=TMG
            IF ((IT.LT.3).OR.(IPRINT.GT.1)) GO TO 114
            TM=TMG+TML
            NG=TMG/TM
            NL=TML/TM
            DO 113 I=1,16
                 X(I)=Z5(I)
                 Y(I)=Z1(I)
                 Z(I)=NG*Z1(I)+NL*Z5(I)
  113       CONTINUE
            CALL DOUT
C           CALCULATE GAS FORMATION VOLUME FACTOR AND CUMULATIVE GAS
C           PRODUCED.
```

```
  114       BG(IT)=0.0282*ZV1(IT)*(T+460.)/P
            CGP(IT)=(TMGS(1)-TMG)*1000./TMGS(1)
C           CALCULATE INSTANTANEOUS RECOVERY DURING DEPLETION.
            IF (GMWC7.LT.1.) GO TO 117
            SUMV=0.
            DO 111 I=5,15
                 IF (Z1(I).LT.1.E-25) GO TO 111
                 SUMV=SUMV+MVOL(I)*Z1(I)*19.715
  111       CONTINUE
            IF (Z1(16).LT.1.E-25) GO TO 112
            SUMV=SUMV+GMWC7*Z1(16)*19.715/(62.4*SGGC7)
  112       ELCE(IT)=SUMV
            ELCP(IT)=SUMV-MVOL(5)*Z1(5)*19.715
            ELCB(IT)=ELCP(IT)-MVOL(6)*Z1(6)*19.715
            ELCPE(IT)=ELCB(IT)-(MVOL(7)*Z1(7)+MVOL(8)*Z1(8))*19.715
  117       IF (MS.EQ.1) GO TO 130
            P=P-100.
            IF (P.LT.PD2) GO TO 115
            GO TO 120
  115       MS=1
            P=14.7
            T=60.
  120 CONTINUE
C     CALCULATE % GAS PRODUCED AND RELATIVE VOLUME OF FLUID.
  130 P=PD1
      T=TR
      MS=0
      WRITE(5,1040)
      WRITE(6,1040)
      DO 150 I=1,IT
            CGP1=CGP(I)/10.
            RV=BG(I)/BG(1)
            WRITE(5,1070)P,T,V(I),RV,CGP1,BG(I),ZV1(I),SGG1(I),
     *      VISG1(I),DEN(I)
            WRITE(6,1070)P,T,V(I),RV,CGP1,BG(I),ZV1(I),SGG1(I),
     *      VISG1(I),DEN(I)
            IF (MS.EQ.1) GO TO 151
            P=P-100.
            IF (I.EQ.IT-1) GO TO 140
            GO TO 150
  140       MS=1
            P=14.7
            T=60.
  150 CONTINUE
C     CALCULATE CUMULATIVE RECOVERY DURING DEPLETION.
  151 P=PD1
      T=TR
      MS=0
      WRITE(5,1041)
      WRITE(6,1041)
```

```
      DO 154 I=1,IT
            PP5=ELCPE(I)*CGP(I)
            PP4=(ELCB(I)-ELCPE(I))*CGP(I)
            PP3=(ELCP(I)-ELCB(I))*CGP(I)
            PP2=(ELCE(I)-ELCP(I))*CGP(I)
            WRITE(5,1042)P,CGP(I),PP2,PP3,PP4,PP5,ELCE(I),ELCP(I),
     *      ELCB(I),ELCPE(I)
            WRITE(6,1042)P,CGP(I),PP2,PP3,PP4,PP5,ELCE(I),ELCP(I),
     *      ELCB(I),ELCPE(I)
            IF (MS.EQ.1) GO TO 155
            P=P-100.
            IF (I.EQ.IT-1) GO TO 152
            GO TO 154
  152       MS=1
            P=14.7
            T=60.
  154 CONTINUE
C     MULTI-STAGE SEPARATION SIMULATION:
C     - PERFORM FLASH CALCULATIONS AT GIVEN PRESSURE AND TEMPERATURE
C      OF EACH SEPARATOR.
  155 DO 158 I=1,16
            Z1(I)=Z4(I)
  158 CONTINUE
  160 MS=0
      IF (NS.EQ.0) GO TO 300
      WRITE(6,1209)
      DO 220 IS=1,NS+1
            IT2=1
            IF (MS.EQ.1) GO TO 163
            P=PSEP(IS)
            T=TSEP(IS)
            IF (P.LT.1.) GO TO 300
            PSEP(IS)=P-14.7
            TSEP(IS)=T
  163       CALL KCOR
  165       CALL FLASH
            CALL MOLES
            CALL EQR
            IF (ABS(SUMER).LT.1.E-5) GO TO 180
            IF (IT2.GE.100) GO TO 175
            IT2=IT2+1
            GO TO 165
  175       WRITE(5,1050)IT2
            WRITE(6,1050)IT2
            GO TO 300
  180       IF (IPRINT.GT.1) GO TO 185
            CALL DOUT
  185       SNL(IS)=1.-NG
C           CALCULATE LIQUID MOLAR VOLUME AND DENSITY.
            DO 190 I=1,16
```

```
                Z1(I)=X(I)
                Z2(I)=X(I)
  190       CONTINUE
            MLG=1
            CALL DENSL
            ULS(IS)=UL
            IF (MS.EQ.0) GO TO 195
            DENO=DENL
  195       IF (NG.LE.0.) GO TO 205
C           CALCULATE GAS SPECIFIC GRAVITY.
            DO 200 I=1,16
                Z2(I)=Y(I)
  200       CONTINUE
            MLG=2
            CALL DENSL
            GO TO 210
  205       SGG=0.
  210       SGGS(IS)=SGG
            IF (MS.EQ.1) GO TO 225
            IF (IS.NE.NS) GO TO 220
            P=14.7
            T=60.
            MS=1
  220 CONTINUE
C     CALCULATE OIL FORMATION VOLUME FACTOR AND SOLUTION GAS-OIL
C     RATIO.
  225 FLS=1.
      FLR=1.
      DO 230 I=1,IS
          FLR=FLR*SNL(I)
  230 CONTINUE
      DO 235 I=1,NS
          FLS=FLS*SNL(I)
          GOR1(I)=(1.-SNL(I))*2130./(SNL(I)*ULS(I))
          GOR2(I)=(1.-SNL(I))*2130./(ULS(IS)*FLR)
          SVF(I)=ULS(I)*FLS/(ULS(IS)*FLR)
  235 CONTINUE
      TOAPI=141.5*62.4/DENO-131.5
      FVF=ULS(1)*SNL(1)/(ULS(IS)*FLR)
      WRITE(5,1220)
      WRITE(6,1220)
      DO 250 I=1,NS
      IF (I.EQ.NS) GO TO 240
      WRITE(5,1230)PSEP(I),TSEP(I),GOR1(I),GOR2(I),SVF(I),SGGS(I)
      WRITE(6,1230)PSEP(I),TSEP(I),GOR1(I),GOR2(I),SVF(I),SGGS(I)
      GO TO 250
  240       WRITE(5,1240)PSEP(I),TSEP(I),GOR1(I),GOR2(I),TOAPI,FVF,
     *      SVF(I),SGGS(I)
            WRITE(6,1240)PSEP(I),TSEP(I),GOR1(I),GOR2(I),TOAPI,FVF,
     *      SVF(I),SGGS(I)
```

```
 250 CONTINUE
     WRITE(5,1260)
     WRITE(6,1260)
 300 CONTINUE
 500 STOP

1010 FORMAT(//3X,'EST.DEW POINT PRESSURE (NEMETH-KENNEDY CORRELATION)
    *= ',3X,F8.2,2X,'PSIA')
1011 FORMAT(/15X,38('*'),/15X,'*',1X,'RETROGRADE CONDENSATE PVT ANALYSI
    *S',1X,'*',/15X,38('*'))
1012 FORMAT(/3X,'METHOD/CORRELATION USED',10X,'PURPOSE',/3X,23('-'),
    *10X,7('-'))
1017 FORMAT(3X,'GRABOWSKI-DAUBERT',16X,'N2-H/C,CO2-H/C AND H2S-H/C BINA
    *RY',/,36X,'INTERACTION PARAMETERS ESTIMATION')
1018 FORMAT(3X,'LAVAL',28X,'N2-H/C AND CO2-H/C BINARY',/,36X,
    *'INTERACTION PARAMETERS ESTIMATION',/3X,'GRABOWSKI-DAUBERT',
    *16X,'H2S-H/C BINARY INTERACTION',/,36X,'PARAMETERS ESTIMATION')
1015 FORMAT(3X,'SUCCESSIVE SUBSTITUTION',10X,'ITERATIVE ESTIMATION OF K
    *-VALUES')
1016 FORMAT(3X,'ACCD. SUCCESSIVE SUBSTITUTION',4X,'ITERATIVE ESTIMATION
    * OF K-VALUES')
1026 FORMAT(/3X,'WHEN METHANE-HEAVY+ INTERACTION FACTOR = ',3X,F6.4,
    */20X,'PRES.DIFFERENCE = ',3X,F8.2,2X,'PSIA',/20X,
    *'EST. DEW POINT PRES. = ',3X,F7.2,2X,'PSIA')
1030 FORMAT(/3X,'CALCULATED FIRST DEW POINT PRESSURE = ',3X,F8.2,2X,
    *'PSIA')
1031 FORMAT(/3X,'INITIAL RESERVOIR CONDITIONS AND COMPOSITION (GIVEN)',
    */3X,'-----------------------------------------------------',/3X,
    *'RESERVOIR TEMPERATURE = ',3X,F5.1,3X,'DEG.F',/3X,
    *'RESERVOIR PRESSURE    = ',3X,F7.2,2X,'PSIA')
1032 FORMAT(3X,'FIRST DEW POINT PRESSURE (EXPT) = NOT GIVEN')
1033 FORMAT(3X,'FIRST DEW POINT PRESSURE (EXPT) = ',3X,F7.2,2X,'PSIA')
1034 FORMAT(//3X,'COMPONENT',18X,
    *'MOLE FRACTION',/3X,'---------',18X,'-------------')
1035 FORMAT(3X,A9,20X,F7.5)
1024 FORMAT(/3X,'HEAVY-PLUS:MOLECULAR WEIGHT = ',3X,F4.0,
    */16X,'SPECIFIC GRAVITY = ',3X,F7.5,/)
1036 FORMAT(/3X,'CALCULATED SECOND DEW POINT PRESSURE = ',2X,F8.2,2X,
    *'PSIA')
1037 FORMAT(/3X,'FLASH SEPARATION OF VAPOR PHASE :',/3X,'-------------
    *--------------------')
1038 FORMAT(/3X,'FLASH SEPARATION OF LIQUID PHASE :',/3X,'-------------
    *---------------------')
1040 FORMAT('1',/32X,35('*'),/32X,'*',1X,'CONSTANT VOLUME DEPLETION STU
    *DY',1X,'*',/,100('-'),/21X,'CUMULATIVE',11X,'CUMULATIVE',13X,
    *'GAS',/21X,'RETROGRADE',2X,'RELATIVE',4X,'GAS',8X,'GAS',7X,'Z',
    *7X,'GAS',7X,'GAS',5X,'LIQUID',/3X,'PRESSURE',3X,'TEMP',2X,
    *'CONDENSATION',2X,'VOLUME',3X,'PRODUCED',5X,'FVF',5X,'FACTOR',
    *2X,'GRAVITY',2X,'VISCOSITY',2X,'DENSITY',/4X,'(PSIA)',3X,
    *'(DEG.F)',4X,'(%)',16X,'(% VOL)',2X,'(CU.FT/SCF)',9X,'(AIR=1)',
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     *4X,'(CP)',5X,'(GM/CC)',/)
1041 FORMAT('1',/34X,'CALCULATED RECOVERY DURING DEPLETION',/37X,
     *'(PER MMSCF OF ORIGINAL FLUID)',/,104('-'),/3X,'PRESSURE',
     *3X,'GAS PHASE',4X,'PLANT PRODUCTS IN GAS PHASE,GALLONS',
     *24X,'GPM',/4X,'(PSIA)',5X,'(MSCF)',6X,'ETHANE',3X,
     *'PROPANE',3X,'BUTANES',3X,'PENTANES+',3X,'ETHANE+',3X,
     *'PROPANE+',3X,'BUTANE+',3X,'PENTANE+',/)
1042 FORMAT(4X,F6.1,4X,F7.2,5X,F5.0,5X,F5.0,5X,F5.0,5X,F5.0,6X,F5.2,
     *5X,F5.2,6X,F5.2,5X,F5.2)
1050 FORMAT(//3X,'K-VALUES DO NOT CONVERGE AFTER = ',3X,I3,2X,
     *'ITERATIONS.')
1070 FORMAT(4X,F6.1,4X,F5.1,4X,F6.2,4X,F7.3,4X,F6.2,4X,F6.4,4X,
     *F6.4,3X,F5.3,4X,F6.4,4X,F6.4)
1110 FORMAT(//3X,'ENTER SEPARATOR PRESSURE (IN PSIA) AND TEMPERATURE
     *(IN DEG.F),RESPECTIVELY.',/3X,'TO DISCONTINUE,TYPE 0.,0.',/)
1126 FORMAT(/3X,'TO PRINT PHASE COMPOSITION,TYPE 1',/3X,'ELSE,TYPE ANY
     *OTHER (LARGER) INTEGER.',/)
1209 FORMAT(1H1,/3X,'MULTI-STAGE SEPARATOR CALCULATIONS',/3X,
     *'------------------------------------')
1220 FORMAT(/3X,'SEPARATOR',11X,'GAS/OIL',2X,'GAS/OIL',2X,'TANK OIL',
     *2X,'FORMATION',2X,'SEPARATOR',/3X,'PRESSURE',4X,'TEMP.',4X,
     *'RATIO',4X,'RATIO',4X,'GRAVITY',4X,'VOLUME',5X,'VOLUME',7X,'GAS',
     */4X,'(PSIG)',4X,'(DEG.F)',4X,'(1)',6X,'(2)',4X,'(DEG.API)',2X,
     *'FACTOR(3)',2X,'FACTOR(4)',3X,'GRAVITY',/)
1230 FORMAT(4X,F5.1,6X,F4.0,5X,F5.0,4X,F5.0,27X,F5.3,6X,F5.3)
1240 FORMAT(4X,F5.1,6X,F4.0,5X,F5.0,4X,F5.0,5X,F4.1,7X,F5.3,6X,F5.3,
     *6X,F5.3)
1260 FORMAT(/3X,'NOTE',/3X,'----',/3X,'(1) GOR IN SCF/BBL',/3X,
     *'(2) GOR IN SCF/STB',/3X,'(3) BBLS OF OIL AT SATURATION PRESSURE
     *PER STB',/3X,'(4) BBLS OF OIL AT GIVEN P&T PER STB')
      END
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```
      SUBROUTINE ACEF
C
C     PURPOSE : ESTIMATE PROPERTIES OF HEAVY-PLUS USING
C             KESSLER-LEE CORRELATIONS.
C
C     INPUT PARAMETERS :
C       MWC7 = MOLECULAR WEIGHT OF HEAVY-PLUS (LB/LB-MOLE)
C       SGC7 = SPECIFIC GRAVITY OF HEAVY-PLUS (WATER=1)
C     OUTPUT PARAMETERS :
C       MVOL(16)= MOLAR VOLUME OF HEAVY-PLUS (CU.FT/LB-MOLE)
C       PC(16) = CRITICAL PRESSURE OF HEAVY-PLUS (PSIA)
C       TB(16) = NORMAL BOILING POINT TEMP. OF HEAVY-PLUS (DEG.R)
C       TC(16) = CRITICAL TEMP. OF HEAVY-PLUS (DEG.F)
C       W(16)  = ACENTRIC FACTOR OF HEAVY-PLUS
C     OTHER PARAMETERS :
C       KW  = WATSON CHARACTERIZATION FACTOR
C       TBR = REDUCED BOILING POINT TEMP.,TB/TC
C
      COMMON/D2/MW(16),MVOL(16)
      COMMON/D3/W(16),PC(16),TC(16)
      COMMON/D9/D(16,16),IBIN,TB(16)
      COMMON/D11/ID,MM
      COMMON/D13/MWC7,SGC7,GMWC7,SGGC7
      REAL KW,MWC7,MW,MVOL
      CHARACTER*1 M1
C     ESTIMATE NORMAL BOILING POINT TEMPERATURE.
      IT=1
      TBC=660.
   10 F=MWC7+12272.6-9486.4*SGC7-(4.6523-3.3287*SGC7)*TBC-(1.3437-1.0358
     **SGC7-.027653*SGC7**2)*1.E7/TBC+(720.79-555.6138*SGC7-14.83386
     **SGC7**2)*1.E7/(TBC**2)-(1.8828-1.52285*SGC7+.04191*SGC7**2)*1.E12
     */(TBC**3)+(181.98-147.1891*SGC7+4.05087*SGC7**2)*1.E12/(TBC**4)
      FP=-4.6523+3.3287*SGC7+(1.3437-1.0358*SGC7-.027653*SGC7**2)*1.E7
     */(TBC**2)-(1441.58-1111.23*SGC7-29.6677*SGC7**2)*1.E7/(TBC**3)+
     *(5.6484-4.5685*SGC7+.12573*SGC7**2)*1.E12/(TBC**4)-(727.92-588.756
     **SGC7+16.2035*SGC7**2)*1.E12/(TBC**5)
      IF (ABS(F).LT.1.E-3) GO TO 20
      TBC=TBC-F/FP
      IF (IT.GE.100) GO TO 50
      IT=IT+1
      GO TO 10
C     ESTIMATE CRITICAL TEMPERATURE AND PRESSURE.
   20 TCC=-118.3+811.*SGC7+(.4244+.1174*SGC7)*TBC+(.4669-3.2623*SGC7)
     **1.E5/TBC
      PC1=8.3634-.0566/SGC7-(.24244+2.2898/SGC7+.11857/(SGC7**2))*1.E-3
     **TBC+(1.4685+3.648/SGC7+.47227/(SGC7**2))*1.E-7*TBC**2-(.42019+
     *1.6977/(SGC7**2))*1.E-10*TBC**3
      PCC=EXP(PC1)
C     ESTIMATE ACENTRIC FACTOR.
      TBR=TBC/(TCC+460.)
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```
      IF (TBR.GT.0.8) GO TO 30
      A1=ALOG(14.7/PCC)-5.92714+6.09648/TBR+1.28862*ALOG(TBR)-.169347
     **TBR**6
      A2=15.2518-15.6875/TBR-13.4721*ALOG(TBR)+.43577*TBR**6
      WC=A1/A2
      GO TO 40
   30 KW=TBC**(1./3.)/SGC7
      WC=-7.904+.1352*KW-.007465*KW**2+8.359*TBR+(1.408-.01063*KW)/TBR
   40 TBC=TBC-460.
      MW(16)=MWC7
      MVOL(16)=MWC7/(62.4*SGC7)
      WR16=(MWC7+28.2608)/347.826
      WRITE(5,100)
      WRITE(6,100)
      WRITE(5,120)TBC,TCC,PCC,WC
      WRITE(6,120)TBC,TCC,PCC,WC
      WRITE(5,130)WR16
   41 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'         ********************************************
     *****************'
      WRITE(*,*)'         *   DO YOU WANT TO USE DIFFERENT HEAVY-PLUS PA
     *RAMETERS ?     *'
      WRITE(*,*)'         *           (I.E. BOILING POINT, CRITICAL TEMP
     *ERATURE,           *'
      WRITE(*,*)'         *             CRITICAL PRESSURE, AND ACENTRIC
     *FACTOR)        *'
      WRITE(*,*)'         ********************************************
     *****************'
      WRITE(*,*)'                                 *       (Y) YES       *'
      WRITE(*,*)'                                 *                     *'
      WRITE(*,*)'                                 *       (N) NO        *'
      WRITE(*,*)'                                 ***********************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,'(A)')M1
      IF (M1.NE.'Y'.AND.M1.NE.'N') THEN
      IF (M1.NE.'y'.AND.M1.NE.'n') GO TO 41
      ENDIF
      IF (M1.EQ.'Y'.OR.M1.EQ.'y') GO TO 45
   43 TB(16)=TBC+460.
      TC(16)=TCC
      PC(16)=PCC
      W(16)=WC
      GO TO 60
   45 WRITE(*,*)
      WRITE(*,*)
```

```
      WRITE(*,*)
      WRITE(*,'(A\)')' HEAVY+ BOILING POINT -->'
      READ(*,*)TBA
      WRITE(*,'(A\)')' HEAVY+ CRITICAL TEMPERATURE -->'
      READ(*,*)TCA
      WRITE(*,'(A\)')' HEAVY+ CRITICAL PRESSURE -->'
      READ(*,*)PCA
      WRITE(*,'(A\)')' HEAVY+ ACENTRIC FACTOR -->'
      READ(*,*)WA
      TB(16)=TBA+460.
      TC(16)=TCA
      PC(16)=PCA
      W(16)=WA
      WRITE(5,160)
      WRITE(6,160)
      WRITE(5,120)TBA,TCA,PCA,WA
      WRITE(6,120)TBA,TCA,PCA,WA
      GO TO 60
   50 WRITE(5,110)
   60 RETURN

  100 FORMAT(//3X,'ESTIMATED PROPERTIES OF HEAVY-PLUS ARE :')
  120 FORMAT(/10X,'NORMAL BOILING POINT TEMP. = ',F7.2,2X,
     *'DEG.F',/10X,'CRITICAL TEMPERATURE = ',2X,F7.2,2X,'DEG.F',
     */10X,'CRITICAL PRESSURE    = ',2X,F7.2,2X,'PSIA',
     */10X,'ACENTRIC FACTOR      = ',2X,F6.4)
  110 FORMAT(/3X,'NO BOILING POINT TEMP. AVAILABLE FROM SUB.ACEF')
  130 FORMAT(/3X,'HEAVY-PLUS ACENTRIC FACTOR VALUE FROM MOL.WT.RELATIONS
     *HIP IS = ',1X,F8.6)
  160 FORMAT(/3X,'NEW HEAVY-PLUS PARAMETERS TO BE USED ARE :')
      END
```

```
      SUBROUTINE BINT
C
C     PURPOSE : ESTIMATE BINARY INTERACTION FACTORS.
C
C     INPUT PARAMETERS :
C       MW  = MOLECULAR WEIGHT (LB/LB-MOLE)
C       SOL = HILDEBRAND'S SOLUBILITY PARAMETER
C       TB  = NORMAL BOILING POINT TEMP. (DEG.R)
C     OUTPUT PARAMETERS :
C       D   = BINARY INTERACTION PARAMETER
C
      COMMON/D2/MW(16),MVOL(16)
      COMMON/D9/D(16,16),IBIN,TB(16)
      DIMENSION SOL(16)
      REAL MW
      DATA SOL/4.44,8.8,7.12,5.68,6.05,6.4,6.73,6.634,7.02,7.02,7.266,
     *7.43,7.551,7.649,7.722,7.55/
      D(1,1)=0.
      D(1,2)=.14
      D(1,3)=.068
      D(2,1)=.14
      D(2,2)=0.
      D(2,3)=.102
      D(3,1)=.068
      D(3,2)=.102
      D(3,3)=0.
      D(1,16)=.16
      D(2,16)=.04
      D(3,16)=.1369
      D(16,1)=.16
      D(16,2)=.04
      D(16,3)=.1369
      IF (IBIN.GT.1) GO TO 21
C     ESTIMATE BINARY INTERACTION PARAMETERS OF CO2,N2 AND H2S
C     SYSTEM USING GRABOWSKI-DAUBERT CORRELATION.
      DO 10 I=4,15
           SOL1=ABS(SOL(I)-SOL(3))
           DUM1=.1294+.0292*SOL1-.0222*SOL1**2
           D(3,I)=DUM1
           D(I,3)=DUM1
   10 CONTINUE
      DO 20 I=4,15
           SOL2=ABS(SOL(I)-SOL(1))
           DUM2=-.0836+.1055*SOL2-.01*SOL2**2
           D(1,I)=DUM2
           D(I,1)=DUM2
   20 CONTINUE
   21 DO 30 I=4,15
      DUM3=.0178+.0244*ABS(SOL(I)-SOL(2))
      D(2,I)=DUM3
```

```
      D(I,2)=DUM3
   30 CONTINUE
C     CALCULATE HYDROCARBON-HYDROCARBON BINARY INTERACTION
C     PARAMETERS.
      DO 35 I=4,16
      DO 35 J=4,16
           DIFF=ABS(MW(I)-MW(J))
           IF (I.GT.J) GO TO 32
           TB1=TB(I)
           GO TO 33
   32      TB1=TB(J)
   33      DUM4=1.8*ALOG(DIFF+1.)**0.92/TB1
           D(I,J)=DUM4
   35 CONTINUE
      IF (IBIN.EQ.1) GO TO 60
C     CALCULATE N2-HYDROCARBONS BINARY INTERACTION PARAMETERS.
      DO 38 I=4,16
           DIFF1=ABS(MW(I)-MW(1))
           DUM5=1.8*ALOG(DIFF1+1.)**1.6/TB(1)
           D(I,1)=DUM5
           D(1,I)=DUM5
   38 CONTINUE
C     CALCULATE CO2-HYDROCARBONS BINARY INTERACTION PARAMETERS.
      DO 41 I=4,16
           DIFF2=ABS(MW(I)-MW(3))
           DUM6=1.8*ALOG(DIFF2+1.)**2.5/TB(3)
           D(I,3)=DUM6
           D(3,I)=DUM6
   41 CONTINUE
   60 RETURN
      END
```

```
      SUBROUTINE DATA1
C
C     PURPOSE : INTERPRET INPUT INFORMATION.
C
      COMMON/D1/CN(16)
      COMMON/D2/MW(16),MVOL(16)
      COMMON/D3/W(16),PC(16),TC(16)
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ
      COMMON/D5/Z(16),X(16),Y(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D13/MWC7,SGC7,GMWC7,SGGC7
      COMMON/D20/INPUTW,GOR,IOUT,FLSH,DIFF,OUTPUT,PSEP(5),TSEP(5)
      COMMON/D21/IPRINT
      REAL K,MWC7,MW,MVOL
      CHARACTER*1 IPRINT
      CHARACTER*9 CN
      CHARACTER*14 FLSH,DIFF,OUTPUT
      IF (INPUTW.EQ.1) GO TO 30
      IF (INPUTW.EQ.2) GO TO 73
      GO TO 97
C     SEPARATOR OUTPUT COMPOSITION GIVEN - RECOMBINATION REQUIRED.
   30 IF (X(16).LT.1.E-25.AND.Y(16).LT.1.E-25) GO TO 50
      CALL ACEF
   50 SUM1=0.
      DO 55 I=1,16
           SUM1=SUM1+X(I)*MVOL(I)
   55 CONTINUE
      CUML=1./SUM1
      CUMG=GOR/379.4
      CUMGL=CUMG+CUML
C     STORES GLOBAL MOLE FRACTION IN Z1.
      DO 60 I=1,16
           Z1(I)=(X(I)*CUML+Y(I)*CUMG)/CUMGL
   60 CONTINUE
      DO 65 J=1,16
           IF (Z1(J).GT.0.) GO TO 70
   65 CONTINUE
   70 SUMZ=0.
      DO 72 I=J+1,16
           SUMZ=SUMZ+Z1(I)
   72 CONTINUE
      Z1(J)=1.-SUMZ
      IF (Z1(16).LT.1.E-25) GO TO 95
      GO TO 95
C     WELL STREAM COMPOSITION IS GIVEN.
   73 SUMZ=0.
      DO 80 I=1,16
           SUMZ=SUMZ+Z1(I)
   80 CONTINUE
      IF (Z1(16).LT.1.E-25) GO TO 95
```

```
      CALL ACEF
   95 P=PR
      T=TR
      GO TO 98
   97 WRITE(5,220)
   98 RETURN
  220 FORMAT(/3X,'INPUT ERROR.')
      END
```

```
      SUBROUTINE DENSL
C
C     PURPOSE : CALCULATE LIQUID MOLAR VOLUME AND DENSITY,AND GAS
C               SPECIFIC GRAVITY.
C
C     INPUT PARAMETERS :
C       MVOL = COMPONENT MOLAR VOLUME (CU.FT/LB-MOLE)
C       MW   = MOLECULAR WEIGHT (LB/LB-MOLE)
C       P    = PRESSURE (PSIA)
C       T    = TEMPERATURE (DEG.F)
C       Z2   = COMPONENT GLOBAL MOLE FRACTION
C       ZL   = LIQUID COMPRESSIBILITY FACTOR
C     OUTPUT PARAMETERS :
C       DENL = LIQUID DENSITY (LB/CU.FT)
C       SGG  = GAS SPECIFIC GRAVITY (AIR=1)
C       VL   = LIQUID MOLAR VOLUME (CU.FT/LB-MOLE)
C
      COMMON/D2/MW(16),MVOL(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D7/ZL,ZV
      COMMON/D14/VL,DENL,SGG,MLG,MS,Z2(16)
      REAL MVOL,MW,MWF
      DATA R/10.731/
      T1=T+460.
      MWF=0.
      VSC=0.
      DO 10 I=1,16
           IF (Z2(I).LT.1.E-25) GO TO 10
           MWF=MWF+Z2(I)*MW(I)
           VSC=VSC+Z2(I)*MVOL(I)
   10 CONTINUE
      IF (MLG.EQ.2) GO TO 30
      VL=ZL*R*T1/P
      DENL=MWF/VL
      IF (MS.EQ.1) GO TO 20
      GO TO 40
C     CALCULATE LIQUID DENSITY AT STANDARD CONDITIONS.
   20 VL=(VL+VSC)/2.
      DENL=MWF/VL
      GO TO 40
   30 SGG=MWF/28.97
   40 RETURN
      END
```

```
      SUBROUTINE DEWPT
C
C     PURPOSE : CALCULATE DEW POINT PRESSURE USING THE METHOD OF
C               SUMMATION OF Z/K.
C
C     INPUT PARAMETERS :
C       K  = EQUILIBRIUM RATIO
C       Z1 = GLOBAL MOLE FRACTION
C     OUTPUT PARAMETERS :
C       PD = DEW POINT PRESSURE (PSIA)
C     FLAG :
C       IDEW = 1 INDICATES UPPER DEW POINT PRESSURE CALCULATIONS.
C       IDEW = 2 INDICATES LOWER DEW POINT PRESSURE CALCULATIONS.
C
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ
      COMMON/D6/P,PR,T,TR
      COMMON/D8/PD,PDC,PDEXP
      COMMON/D15/IKV,METH
      COMMON/D17/IDEW
      REAL K
      LD=1
      LD1=1
      PP=1.5*PDC
   10 IT=1
      CALL KCOR
   12 CALL FLASH
      CALL MOLES
      CALL EQR
      IF (ABS(SUMER).LT.1.E-5) GO TO 18
      IF (IT.GE.50) GO TO 65
      IT=IT+1
      GO TO 12
   18 F=0.
      DO 20 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 20
           F=F+Z1(I)/K(I)
   20 CONTINUE
      IF (IDEW.EQ.2) GO TO 35
      IF (LD.EQ.2) GO TO 25
      IF (F.GE.1.) GO TO 30
      GO TO 40
   22 P=P-100.
      IF (P.GT.14.7) GO TO 10
      P=14.7
      LD1=2
      GO TO 10
   25 IF (F.LE.1.) GO TO 50
   30 P=P+10.
      LD=2
      IF (P.GT.PP) GO TO 65
```

```
      GO TO 10
   35 IF (LD.EQ.2) GO TO 55
      IF (F.LE.1.) GO TO 30
      GO TO 22
   40 IF (LD1.EQ.2) GO TO 60
      GO TO 22
   50 P=P-5.
      GO TO 70
   55 IF (F.GE.1.) GO TO 50
      GO TO 30
   60 P=0.
      GO TO 70
   65 WRITE(5,100)
      WRITE(6,100)
      P=0.
   70 PD=P
      RETURN

  100 FORMAT(/3X,'NO CONVERGENCE IN SUB. DEWPT AFTER 50 ITERATIONS')
      END
```

```
      SUBROUTINE DEWCOR
C
C     PURPOSE : CALCULATE DEW POINT PRESSURE USING NEMETH-KENNEDY
C               CORRELATION (1967)
C
C     INPUT PARAMETERS :
C       MWC7 = MOLECULAR WEIGHT OF HEAVY-PLUS (LB/LB-MOLE)
C       SGC7 = SPECIFIC GRAVITY OF HEAVY-PLUS (WATER=1)
C       T    = TEMPERATURE (DEG.F)
C       Z1   = GLOBAL MOLE FRACTION
C     OUTPUT PARAMETERS :
C       PDC  = CALCULATED DEW POINT PRESSURE (PSIA)
C
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ
      COMMON/D6/P,PR,T,TR
      COMMON/D8/PD,PDC,PDEXP
      COMMON/D13/MWC7,SGC7,GMWC7,SGGC7
      DIMENSION A(11)
      REAL MWC7
C     CORRELATION COEFFICIENTS.
      DATA A/-2.0623054,6.6259728,-4.4670559E-3,1.0448346E-4,3.2673714
     *E-2,-3.6453277E-3,7.4299951E-5,-.11381195,6.2476497E-4,-1.0716866
     *E-6,10.746622/

      A1=A(1)*(0.2*Z1(1)+Z1(2)+Z1(3)+0.4*Z1(4)+Z1(5)+2.0*(Z1(6)+Z1(7)
     *+Z1(8))+Z1(9)+Z1(10)+Z1(11))
      A3=A(3)*Z1(4)/(Z1(16)+.002)
      A4=A(4)*(T+460.)
      IF (Z1(16).LT.1.E-25) GO TO 10
      A2=A(2)*SGC7
      B1=Z1(16)*MWC7
      A5=A(5)*B1
      A6=A(6)*B1**2
      A7=A(7)*B1**3
      B2=MWC7/(SGC7+.0001)
      A8=A(8)*B2
      A9=A(9)*B2**2
      A10=A(10)*B2**3
      GO TO 20
   10 A2=0.
      A5=0.
      A6=0.
      A7=0.
      A8=0.
      A9=0.
      A10=0.
   20 A11=A(11)
      PDC=EXP(A1+A2+A3+A4+A5+A6+A7+A8+A9+A10+A11)
      RETURN
      END
```

```
      SUBROUTINE DOUT
C
C     PURPOSE : PRINT OUTPUT DATA ON PHASE COMPOSITION.
C
C     OUTPUT PARAMETERS :
C        CN   = COMPONENT NAME
C        K    = EQUILIBRIUM RATIO
C        NG   = GAS MOLE FRACTION
C        NL   = LIQUID MOLE FRACTION
C        P    = PRESSURE (PSIA)
C        SUMX = SUM OF COMPONENT LIQUID MOLE FRACTIONS
C        SUMY = SUM OF COMPONENT GAS MOLE FRACTIONS
C        SUMZ = SUM OF COMPONENT GLOBAL MOLE FRACTIONS
C        X    = COMPONENT LIQUID MOLE FRACTION
C        Y    = COMPONENT GAS MOLE FRACTION
C        Z    = COMPONENT GLOBAL MOLE FRACTION
C        ZL   = LIQUID COMPRESSIBILITY/DEVIATION FACTOR
C        ZV   = GAS COMPRESSIBILITY/DEVIATION FACTOR
C
      COMMON/D1/CN(16)
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ
      COMMON/D5/Z(16),X(16),Y(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D7/ZL,ZV
      COMMON/D10/NG,NL,SUMX,SUMY
      COMMON/D12/NCOM
      CHARACTER*9 CN
      REAL K,NG,NL
      WRITE(4,101)
      WRITE(4,100)
      WRITE(4,110)P,T,NG,NL
      WRITE(4,125)
      DO 16 I=1,16
           IF (Z(I).LT.1.E-25) GO TO 16
           WRITE(4,135)CN(I),Z(I),K(I),X(I),Y(I)
   16 CONTINUE
      WRITE(4,155)SUMZ,SUMX,SUMY
      WRITE(4,180)ZL,ZV
      GO TO 50

   50 RETURN
  101 FORMAT(/15X,38('*'),/15X,'*',1X,'RETROGRADE CONDENSATE PVT ANALYSI
     *S',1X,'*',/15X,38('*'))
  100 FORMAT(/3X,'FLASH SEPARATION CALCULATIONS.',/3X,'----------------
     *----------')
  110 FORMAT(/3X,'PRESSURE = ',3X,F6.1,2X,'PSIA',/3X,'TEMPERATURE = ',
     *3X,F6.1,2X,'DEG.F',/3X,'GAS MOLE FRACTION = ',3X,F6.4,/3X,
     *'LIQUID MOLE FRACTION = ',3X,F6.4)
  125 FORMAT(/18X,'TOTAL',5X,'EQUILIBRIUM',5X,'LIQUID',8X,'GAS',/3X,
     *'COMPONENT',2X,'COMPOSITION',2X,'RATIO(CAL)',3X,'COMPOSITION',
```

```
   *2X,'COMPOSITION')
135 FORMAT(3X,A9,3X,F6.4,6X,F8.4,6X,F6.4,7X,F6.4)
155 FORMAT(16X,F6.4,20X,F6.4,7X,F6.4)
180 FORMAT(3X,'Z-FACTOR',32X,F6.4,7X,F6.4)
    END
```

```
      SUBROUTINE EQR
C
C     PURPOSE : CALCULATE EQUILIBRIUM RATIO OF EACH COMPONENT USING
C               THE PENG-ROBINSON EQUATION OF STATE.
C
C     INPUT PARAMETERS :
C       D  = BINARY INTERACTION FACTOR
C       P  = PRESSURE (PSIA)
C       T  = TEMPERATURE (DEG.F)
C       TC = CRITICAL TEMPERATURE (DEG.R)
C       W  = ACENTRIC FACTOR
C       X  = COMPONENT LIQUID MOLE FRACTION
C       Y  = COMPONENT GAS MOLE FRACTION
C       ZL = LIQUID COMPRESSIBILITY/DEVIATION FACTOR
C       ZV = GAS COMPRESSIBILITY/DEVIATION FACTOR
C     OUTPUT PARAMETERS :
C       K  = EQUILIBRIUM RATIO
C     OTHER PARAMETERS :
C       FRAT = FUGACITY RATIO (IN ACC. SUCCESSIVE SUBSTITUTION)
C       FUGR = FUGACITY RATIO (IN SUCCESSIVE SUBSTIUTTION)
C       LAMDA = ACCELERATION FACTOR
C       OLDFR = PREVIOUS FUGACITY RATIO
C     FLAG :
C       IKV = 2 INDICATES EQUILIBRIUM RATIOS ARE CALCULATED BY
C       USING THE P-R EQUATION OF STATE
C
      COMMON/D3/W(16),PC(16),TC(16)
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ
      COMMON/D5/Z(16),X(16),Y(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D7/ZL,ZV
      COMMON/D9/D(16,16),IBIN,TB(16)
      COMMON/D15/IKV,METH
      DIMENSION A(16),B(16),TC1(16),XA(16),YA(16),FRAT(16),OLDFR(16),
     *PK(16)
      REAL K,LAMDA,MVOL,MW,NG,NL
      DATA R/10.731/
      DATA OLDFR/16*1.0/
      DATA ERROR/1.E-5/
      T1=T+460.
      DO 20 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 10
           TC1(I)=TC(I)+460.
           TRED=T1/TC1(I)
           A1=.37464+1.54226*W(I)-.26992*W(I)**2
           A2=1.+A1*(1.-SQRT(TRED))
           A3=.45724*(R**2)*(TC1(I)**2)/PC(I)
           A(I)=A3*(A2**2)
           B(I)=.0778*R*TC1(I)/PC(I)
           GO TO 20
```

```
   10      A(I)=0.
           B(I)=0.
   20 CONTINUE
C     CALCULATE Z-FACTOR OF LIQUID PHASE.
      ASL=0.
      BSL=0.
      DO 40 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 35
           BSL=BSL+X(I)*B(I)
           XL=0.
           DO 30 J=1,16
           IF (Z1(J).LT.1.E-25) GO TO 30
           AIJ=(1.-D(I,J))*(SQRT(A(I)*A(J)))
           ASL=ASL+X(I)*X(J)*AIJ
           XL=XL+X(J)*AIJ
   30      CONTINUE
           XA(I)=XL
           GO TO 40
   35      XA(I)=0.
   40 CONTINUE
      AL=ASL*P/((R*T1)**2)
      BL=BSL*P/(R*T1)
      CALL QROOT(AL,BL,ZL,1)
C     CALCULATE Z-FACTOR OF VAPOR PHASE.
      ASV=0.
      BSV=0.
      DO 60 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 55
           BSV=BSV+Y(I)*B(I)
           YV=0.
           DO 50 J=1,16
           IF (Z1(J).LT.1.E-25) GO TO 50
           AIJ=(1.-D(I,J))*SQRT(A(I)*A(J))
           ASV=ASV+Y(I)*Y(J)*AIJ
           YV=YV+Y(J)*AIJ
   50      CONTINUE
           YA(I)=YV
           GO TO 60
   55      YA(I)=0.
   60 CONTINUE
      AV=ASV*P/(R*T1)**2
      BV=BSV*P/(R*T1)
      CALL QROOT(AV,BV,ZV,2)
      IF ((ASL.LT.1.E-25).OR.(ASV.LT.1.E-25)) GO TO 61
      GO TO 59
   61 SUMER=0.
      GO TO 95
C     CALCULATE COMPONENT FUGACITY COEFFICIENTS AND K-VALUES.
   59 CONS1=(ZL-1.)/BSL-(ZV-1.)/BSV
      CONS2=ALOG((ZV-BV)/(ZL-BL))
```

```
      CONSL=(AL/(SQRT(8.)*BL))*ALOG((ZL+(SQRT(2.)+1.)*BL)/(ZL-(SQRT(2.)
     *     -1.)*BL))
      CONSV=(AV/(SQRT(8.)*BV))*ALOG((ZV+(SQRT(2.)+1.)*BV)/(ZV-(SQRT(2.)
     *     -1.)*BV))
      IF (METH.GT.1) GO TO 81
C     ESTIMATE K-VALUES USING SUCCESSIVE SUBSTITUTION METHOD.
      SUMER=0
      DO 80 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 65
           FUGR=ALOG(X(I)/Y(I))+B(I)*CONS1+CONS2-CONSL*(2.*XA(I)/ASL-
     *          B(I)/BSL)+CONSV*(2.*YA(I)/ASV-B(I)/BSV)
           PK(I)=K(I)
           K(I)=PK(I)*EXP(FUGR)
           DIF=K(I)-PK(I)
           PROD=K(I)*PK(I)
           IF (PROD.LT.1.E-20) PROD=1.E-20
           SUMER=SUMER+DIF*DIF/PROD
           GO TO 80
   65      K(I)=0.
   80 CONTINUE
      GO TO 95
C     ESTIMATE K-VALUES USING ACCELERATED SUCCESSIVE SUBSTITUTION
C     METHOD.
   81 SUMFR1=0.
      SUMFR2=0.
      SUMER=0.
      RMAX=0.
      DO 82 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 82
           FRAT(I)=ALOG(X(I)/Y(I))+B(I)*CONS1+CONS2-CONSL*(2.*XA(I)/ASL
     *          -B(I)/BSL)+CONSV*(2.*YA(I)/ASV-B(I)/BSV)
           SUMFR1=SUMFR1+OLDFR(I)**2
           SUMFR2=SUMFR2+OLDFR(I)*FRAT(I)
           RMAX=AMAX1(RMAX,ABS(FRAT(I)))
           OLDFR(I)=FRAT(I)
   82 CONTINUE
      IF (IKV.EQ.1) GO TO 83
      DIF=ABS(SUMFR1-SUMFR2)
      IF (DIF.GT.(ERROR**2*SUMFR2)) GO TO 84
   83 LAMDA=1.0
      GO TO 86
   84 LAMDA=SUMFR1/DIF*LAMDA
      ALIM=LAMDA*RMAX
      IF (ALIM.GT.6.) LAMDA=6./RMAX
   86 DO 88 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 87
           PK(I)=K(I)
           K(I)=PK(I)*EXP(LAMDA*FRAT(I))
           DIF=K(I)-PK(I)
           PROD=K(I)*PK(I)
```

```
      IF (PROD.LT.1.E-20) PROD=1.E-20
      SUMER=SUMER+DIF*DIF/PROD
      GO TO 88
87    K(I)=0.
88 CONTINUE
95 IKV=2
   RETURN
   END
```

```
      SUBROUTINE FLASH
C
C     PURPOSE : CALCULATE PHASE MOLE FRACTION USING COMBINED BISECTION/
C               SECANT/INVERSE QUADRATIC INTERPOLATION METHOD.
C
C     INPUT PARAMETERS :
C       K  = EQUILIBRIUM RATIO
C       Z1 = GLOBAL MOLE FRACTION
C     OUTPUT PARAMETERS :
C       NG = GAS MOLE FRACTION
C       NL  = LIQUID MOLE FRACTION
C
      COMMON/D10/NG,NL,SUMX,SUMY
      EXTERNAL FX
      REAL NG,NL
      A=1.E-10
      B=1.0
      TOL=1.E-10
      NG=ZERDIN(A,B,FX,TOL)
      NL=1.-NG
      RETURN
      END
```

```
      REAL FUNCTION FX(X)
C
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ
      REAL K
      DOUBLE PRECISION DIFF
      F=0.0
      DO 10 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 10
           DIFF=K(I)-1.
           F=F+Z1(I)*DIFF/(1.+X*DIFF)
   10 CONTINUE
      FX=F
      RETURN
      END
```

```
      REAL FUNCTION ZEROIN(AX,BX,FX,TOL)
C
C     PURPOSE : COMPUTE A ROOT OF FUNCTION FX(X) IN THE INTERVAL
C               AX,BX
C
C     INPUT PARAMETERS:
C       AX  = LEFT ENDPOINT OF INITIAL INTERVAL
C       BX  = RIGHT ENDPOINT OF INITIAL INTERVAL
C       FX  = FUNCTION SUBPROGRAM WHICH EVALUATES FX(X) FOR ANY
C             X IN THE INTERVAL AX,BX
C       TOL = DESIRED TOLERANCE (1.E-10)
C
C     OUTPUT PARAMETER:
C       ZEROIN = COMPUTED ROOT OF FUNCTION FX(X)
C
C     COMPUTE EPS,THE RELATIVE MACHINE PRECISION.
C
      EPS=1.0
   10 EPS=EPS/2.0
      TOL1=1.0+EPS
      IF (TOL1.GT.1.0) GO TO 10
C     INITIALIZATION.
      A=AX
      B=BX
      FA=FX(A)
      FB=FX(B)
C     BEGIN STEP
   20 C=A
      FC=FA
      D=B-A
      E=D
   30 IF (ABS(FC).GE.ABS(FB)) GO TO 40
      A=B
      B=C
      C=A
      FA=FB
      FB=FC
      FC=FA
C     CONVERGENCE TEST.
   40 TOL1=2.0*EPS*ABS(B)+0.5*TOL
      XM=0.5*(C-B)
      IF (ABS(XM).LE.TOL1) GO TO 90
      IF (FB.EQ.0.0) GO TO 90
C     IS BISECTION NECESSARY.
      IF (ABS(E).LT.TOL1) GO TO 70
      IF (ABS(FA).LE.ABS(FB)) GO TO 70
C     IS QUADRATIC INTERPOLATION POSSIBLE.
      IF (A.NE.C) GO TO 50
C     LINEAR INTERPOLATION (SECANT METHOD).
      S=FB/FA
```

```
      P=2.0*XM*S
      Q=1.0-S
      GO TO 60
C     INVERSE QUADRATIC FUNCTION.
   50 Q=FA/FC
      R=FB/FC
      S=FB/FA
      P=S*(2.0*XM*(Q-R)-(B-A)*(R-1.0))
      Q=(Q-1.0)*(R-1.0)*(S-1.0)
C     ADJUST SIGNS.
   60 IF (P.GT.0.0) Q=-Q
      P=ABS(P)
C     IS INTERPOLATION ACCEPTABLE.
      IF ((2.0*P).GE.(3.0*XM*Q-ABS(TOL1*Q))) GO TO 70
      IF (P.GE.ABS(0.5*E*Q)) GO TO 70
      E=D
      D=P/Q
      GO TO 80
C     BISECTION.
   70 D=XM
      E=D
C     COMPLETE STEP.
   80 A=B
      FA=FB
      IF (ABS(D).GT.TOL1) B=B+D
      IF (ABS(D).LE.TOL1) B=B+SIGN(TOL1,XM)
      FB=FX(B)
      IF ((FB*(FC/ABS(FC))).GT.0.0) GO TO 20
      GO TO 30
C     DONE
   90 ZEROIN=B
      RETURN
      END
```

```
      SUBROUTINE KCOR
C
C     PURPOSE : ESTIMATE INITIAL SET OF EQUILIBRIUM RATIOS USING
C               CORRELATION.
C
C     INPUT PARAMETERS :
C       P   = PRESSURE (PSIA)
C       PC  = CRITICAL PRESSURE (PSIA)
C       T   = TEMPERATURE (DEG.F)
C       TC  = CRITICAL TEMPERATURE (DEG.F)
C       W   = ACENTRIC FACTOR
C     OUTPUT PARAMETERS :
C       K   = EQUILIBRIUM RATIO
C     FLAG :
C       IKV = 1 INDICATES EQUILIBRIUM RATIOS ARE ESTIMATED FROM
C       CORRELATION.
C
      COMMON/D3/W(16),PC(16),TC(16)
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ
      COMMON/D6/P,PR,T,TR
      COMMON/D15/IKV,METH
      DIMENSION TC1(16)
      REAL K
      IKV=1
      T1=T+460.
      DO 20 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 10
           TC1(I)=TC(I)+460.
           K(I)=EXP(5.37*(1.+W(I))*(1.-TC1(I)/T1))/(P/PC(I))
           GO TO 20
   10      K(I)=0.
           TC1(I)=0.
   20 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MOLES
C
C     PURPOSE : CALCULATE COMPONENT PHASE MOLE FRACTIONS.
C
C     INPUT PARAMETERS :
C       K    = EQUILIBRIUM RATIO
C       NG   = GAS MOLE FRACTION
C       NL   = LIQUID MOLE FRACTION
C       Z1   = GLOBAL COMPONENT MOLE FRACTION
C     OUTPUT PARAMETERS :
C       SUMX = SUM OF COMPONENT LIQUID MOLE FRACTIONS
C       SUMY = SUM OF COMPONENT GAS MOLE FRACTIONS
C       SUMZ = SUM OF GLOBAL COMPONENT MOLE FRACTIONS
C       X    = COMPONENT LIQUID MOLE FRACTION
C       Y    = COMPONENT GAS MOLE FRACTION
C
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ
      COMMON/D5/Z(16),X(16),Y(16)
      COMMON/D10/NG,NL,SUMX,SUMY
      REAL K,NG,NL
C     CALCULATE COMPONENT MOLE FRACTIONS.
      SUMX=0.
      SUMY=0.
      IF ((1.-NL).LT.1.E-4) GO TO 60
      IF (NL.LT.1.E-4) GO TO 70
      NG=1.-NL
      IF (NL.GT.NG) GO TO 55
      DO 50 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 40
           X(I)=Z1(I)/(K(I)+NL*(1.-K(I)))
           Y(I)=K(I)*X(I)
           SUMX=SUMX+X(I)
           SUMY=SUMY+Y(I)
           GO TO 50
   40      X(I)=0.
           Y(I)=0.
   50 CONTINUE
      GO TO 90
   55 DO 58 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 56
           X(I)=Z1(I)/(1.+NG*(K(I)-1.))
           Y(I)=K(I)*X(I)
           SUMX=SUMX+X(I)
           SUMY=SUMY+Y(I)
           GO TO 58
   56      X(I)=0.
           Y(I)=0.
   58 CONTINUE
      GO TO 90
   60 NL=1.
```

```
      NG=0.
      DO 65 I=1,16
           X(I)=Z1(I)
           Y(I)=0.
           SUMX=SUMX+X(I)
   65 CONTINUE
      GO TO 90
   70 NL=0.
      NG=1.
      DO 75 I=1,16
           X(I)=0.
           Y(I)=Z1(I)
           SUMY=SUMY+Y(I)
   75 CONTINUE
   90 RETURN
      END
```

```
      SUBROUTINE PHASEB
C
C     PURPOSE : IDENTIFY TYPE OF FLUID SYSTEM USING SUMMATION OF
C               Z*K AND Z/K.
C
C     INPUT PARAMETERS :
C       K  = EQUILIBRIUM RATIO
C       P  = PRESSURE (PSIA)
C       Z1 = GLOBAL COMPONENT MOLE FRACTION
C     OUTPUT PARAMETERS :
C       ID = TYPE OF FLUID SYSTEM; ID=1 INDICATES BLACK/VOLATILE
C            OIL SYSTEM, AND ID=3 INDICATES RETROGRADE CONDENSATE
C            SYSTEM. ID=2 INDICATES TWO-PHASE FLUID BEHAVIOR.
C
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ
      COMMON/D6/P,PA,T,TR
      COMMON/D11/ID,MM
      REAL K
C     CALCULATE K-VALUES AT GIVEN PRESSURE $ TEMPERATURE.
      ID=4
   10 ITE=1
      CALL KCOR
   13 CALL FLASH
      CALL MOLES
      CALL EQR
      IF (ABS(SUMER).LT.1.E-5) GO TO 20
      IF (ITE.GE.100) GO TO 16
      ITE=ITE+1
      GO TO 13
   16 WRITE(5,190)
      WRITE(6,190)
      ID=0
      GO TO 80
C     CHECK FOR PHASE BEHAVIOR OF FLUID.
   20 SUMKZ1=0.
      SUMKZ2=0.
      DO 30 I=1,16
           IF (Z1(I).LT.1.E-25) GO TO 30
           SUMKZ1=SUMKZ1+Z1(I)*K(I)
           SUMKZ2=SUMKZ2+Z1(I)/K(I)
   30 CONTINUE
      IF (ABS(SUMKZ1-1.0).LT.1.E-4) GO TO 40
      IF (ABS(SUMKZ2-1.0).LT.1.E-4) GO TO 45
      IF ((SUMKZ1.GT.1.0).AND.(SUMKZ2.GT.1.0)) GO TO 50
      IF ((SUMKZ1.LT.1.0).AND.(SUMKZ2.LT.1.0)) GO TO 55
      IF (SUMKZ1.LT.1.0) GO TO 60
      IF (ID.EQ.2) GO TO 47
      GO TO 47
   40 IF (ID.EQ.2) GO TO 65
      GO TO 65
```

```
 45 IF (ID.EQ.2) GO TO 47
 47 ID=3
    GO TO 70
 50 IF (ID.EQ.2) GO TO 70
    ID=2
    GO TO 70
 55 CONTINUE
    ID=0
    GO TO 70
 60 IF (ID.EQ.2) GO TO 65
 65 ID=1
 70 CONTINUE
    IF (ID.NE.2) GO TO 80
    P=P+100.
    GO TO 10
 80 RETURN
190 FORMAT(/3X,'NO CONVERGENCE IN SUB. PHASEB AFTER 100 ITERATIONS.')
    END
```

```
      SUBROUTINE QROOT(A,B,ROOT,L)
C
C     PURPOSE : CALCULATE THE REAL ROOTS OF THE PENG-ROBINSON CUBIC
C               EQUATION OF STATE IN Z-FACTOR.
C
C     INPUT PARAMETERS :
C       A,B = PARAMETERS OBTAINED FROM THE PENG-ROBINSON
C                   EQUATION OF STATE.
C     OUTPUT PARAMETERS :
C       ROOT = LIQUID OR GAS COMPRESSIBILITY/DEVIATION FACTOR
C     FLAG :
C       L = 1 INDICATES LIQUID PHASE.
C       L = 2 INDICATES GAS PHASE.
C
      C1=B*(B*B+B-A)
      C2=A-B*(B*3.+2.)
      C3=B-1.
      B1=(3.*C2-C3*C3)/3.
      B0=(2.*(C3**3)-9.*C2*C3+27.*C1)/27.
      DET=(B1/3.)**3+(B0/2.)**2
      IF (DET.LT.0.) GO TO 10
      IF (DET.LT.1.E-20) GO TO 20
      L1=1
      GO TO 20
   10 IF (B1.GT.0.) GO TO 95
      PHI=ACOS((-B0/2.)*(-3./B1)**1.5)
      PI=2.*ASIN(1.0)
      B2=2.*SQRT(-B1/3.)
      Y1=B2*COS(PHI/3.)-C3/3.
      Y2=B2*COS(PHI/3.+2.*PI/3.)-C3/3.
      Y3=B2*COS(PHI/3.+4.*PI/3.)-C3/3.
      IF (L.EQ.1) GO TO 15
      ROOT=AMAX1(Y1,Y2,Y3)
      GO TO 90
   15 IF (Y1.LE.0.) Y1=1.E6
      IF (Y2.LE.0.) Y2=1.E6
      IF (Y3.LE.0.) Y3=1.E6
      ROOT=AMIN1(Y1,Y2,Y3)
      IF (ROOT.GT.1.E5) GO TO 95
      GO TO 90
   20 DET1=SQRT(DET)
      F1=-B0/2.+DET1
      F2=-B0/2.-DET1
      IF (F1.LT.0.0.AND.F2.LT.0.0) GO TO 30
      IF (F1.LT.0.0.AND.F2.GT.0.0) GO TO 40
      IF (F1.GT.0.0.AND.F2.LT.0.0) GO TO 50
      Y1=F1**(1./3.)+F2**(1./3.)-C3/3.
      GO TO 60
   30 F1=-F1
      F2=-F2
```

```
      Y1=-(F1**(1./3.)+F2**(1./3.))-C3/3.
      GO TO 60
   40 F1=-F1
      Y1=-(F1**(1./3.))+F2**(1./3.)-C3/3.
      GO TO 60
   50 F2=-F2
      Y1=F1**(1./3.)-(F2**(1./3.))-C3/3.
   60 IF (L1.EQ.1) GO TO 70
      F4=-B0/2.
      IF (F4.LT.0.) THEN
         F4=-F4
         Y2=-(F4**(1./3.))-C3/3.
      ELSE
         Y2=F4**(1./3.)-C3/3.
      ENDIF
      IF (L.EQ.1) GO TO 65
      ROOT=AMAX1(Y1,Y2)
      GO TO 90
   65 IF (Y1.LE.0.0.AND.Y2.LE.0.) GO TO 95
      IF (Y1.LE.0.) THEN
         ROOT=Y2
      ELSE
         ROOT=Y1
      ENDIF
      GO TO 90
   70 ROOT=Y1
      GO TO 90
   95 WRITE(5,100)
      WRITE(6,100)
   90 L1=2
      RETURN
  100 FORMAT(/3X,'NO ROOTS AVAILABLE IN SUB.QROOT.')
      END
```

```
      SUBROUTINE VISCG(PRES,T2,GG,Z,VGAS)
C
C     PURPOSE : CALCULATE GAS VISCOSITY USING LEE-EAKIN CORRELATION.
C
C     INPUT PARAMETERS :
C       GG   = GAS SPECIFIC GRAVITY (AIR=1)
C       PRES = PRESSURE (PSIA)
C       T2   = TEMPERATURE (DEG.F)
C       Z    = GAS COMPRESSIBILITY/DEVIATION FACTOR
C     OUTPUT PARAMETERS :
C       VGAS = GAS VISCOSITY (CP)
C
      REAL K
      IF (Z.LE.0.) GO TO 10
      TEMP=T2+460.
      K=(9.4+.58*GG)*(TEMP**1.5)/(209.+551.*GG+TEMP)
      X=3.5+986./TEMP+.2897*GG
      G=2.4-.2*X
      DENS=.043264*GG*PRES/(Z*TEMP)
      VGAS=K*EXP(X*DENS**G)/10000.
      GO TO 20
   10 VGAS=0.
   20 RETURN
      END
```

```
      SUBROUTINE INPUT
C
C     PURPOSE : READS INPUT DATA
C
      COMMON/D1/CN(16)
      COMMON/D4/K(16),SUMER,Z1(16),SUMZ
      COMMON/D5/Z(16),X(16),Y(16)
      COMMON/D6/P,PR,T,TR
      COMMON/D8/PD,PDC,PDEXP
      COMMON/D9/D(16,16),IBIN,TB(16)
      COMMON/D13/MWC7,SGC7,GMWC7,SGGC7
      COMMON/D15/IKV,METH
      COMMON/D20/INPUTW,GGR,IOUT,FLSH,DIFF,OUTPUT,PSEP(5),TSEP(5)
      COMMON/D21/IPRINT
      COMMON/D22/NS
      CHARACTER*14 INFILE,FLSH,DIFF,OUTPUT
      CHARACTER*9 CN
      CHARACTER*1 RESP,IPRINT
      REAL MWC7
      DO 1 I=1,16
        X(I)=1.
        Y(I)=1.
        Z1(I)=1.
    1 CONTINUE
      WRITE(*,*)'              ***GAS CONDENSATE PVT ANALYSIS***'
    2 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'            ****************************************'
      WRITE(*,*)'            *  (1) INPUT DATA FOR CALCULATION    *'
      WRITE(*,*)'            *                OR                  *'
      WRITE(*,*)'            *  (2) RETRIEVE DATA INPUT FILE      *'
      WRITE(*,*)'            ****************************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,*)INPUT
      IF (INPUT.LT.1.OR.INPUT.GT.2) GO TO 2
      IF (INPUT.EQ.2) THEN
      WRITE(*,'(A\)')' NAME OF INPUT FILE TO BE RETRIEVED ? -->'
      READ(*,'(A)')INFILE
      OPEN(9,FILE=INFILE,STATUS='OLD')
      READ(9,*)INPUTW,(X(I),Y(I),Z1(I),I=1,16),MWC7,SGC7,GMWC7,SGGC7,
     *GGR,PR,TR,PBEXP,METH,IBIN,IOUT
      READ(9,'(4A)')FLSH,DIFF,OUTPUT,IPRINT
      READ(9,*)NS
      IF (NS.LT.0.OR.NS.GT.5) GO TO 35
      IF (NS.GT.0) THEN
      READ(9,*)(PSEP(I),TSEP(I),I=1,NS)
```

```
      ENDIF
      IF (INPUTW.EQ.1.OR.INPUTW.EQ.2) GO TO 12
   35 WRITE(*,'(A)')' BAD INPUT FILE'
      GO TO 2
      ENDIF
    3 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'                    **************************'
      WRITE(*,*)'                    *     SAMPLE TYPE        *'
      WRITE(*,*)'                    **************************'
      WRITE(*,*)'                    *  (1) RECOMBINATION     *'
      WRITE(*,*)'                    *         OR             *'
      WRITE(*,*)'                    *  (2) WELL-STREAM       *'
      WRITE(*,*)'                    **************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,*)INPUTW
      IF (INPUTW.LT.1.OR.INPUTW.GT.2) GO TO 3
      IF (INPUTW.EQ.2) GO TO 5
      WRITE(*,'(A)')' INPUT MOLE FRACTIONS FOR THE FOLLOWING COMPONENTS'
      WRITE(*,'(A)')' (LIQUID FRACTION,VAPOR FRACTION)'
      DO 4 I=1,16
       WRITE(*,'(A,A9,A\)')' ',CN(I),'  -->'
       READ(*,*)X(I),Y(I)
    4 CONTINUE
      GO TO 7
    5 WRITE(*,'(A)')' INPUT MOLE FRACTIONS FOR THE FOLLOWING COMPONENTS'
      DO 6 I=1,16
       WRITE(*,'(A,A9,A\)')' ',CN(I),'  -->'
       READ(*,*)Z1(I)
    6 CONTINUE
    7 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A)')' ENTER THE FOLLOWING PARAMETERS'
      WRITE(*,*)
      WRITE(*,'(A\)')' MOLECULAR WEIGHT OF THE LIQUID PHASE HEAVY+ -->'
      READ(*,*)XMWC7
      WRITE(*,'(A\)')' SPECIFIC GRAVITY OF THE LIQUID PHASE HEAVY+ -->'
      READ(*,*)SGC7
      WRITE(*,'(A)')' MOLECULAR WEIGHT OF THE VAPOR PHASE HEAVY+'
      WRITE(*,'(A)')' IF NOT AVAILABLE, TYPE 0.'
      WRITE(*,'(A\)')' -->'
      READ(*,*)GMWC7
      WRITE(*,'(A)')' SPECIFIC GRAVITY OF THE VAPOR PHASE HEAVY+'
      WRITE(*,'(A)')' IF NOT AVAILABLE, TYPE 0.'
      WRITE(*,'(A\)')' -->'
```

```
      READ(*,*)SGGC7
      WRITE(*,*)
      WRITE(*,'(A)')' SYSTEM GAS-OIL RATIO (SCF/STB)'
      WRITE(*,'(A)')' FOR WELL-STREAM SAMPLE, TYPE 0.'
      WRITE(*,'(A\)')' -->'
      READ(*,*)GOR
      WRITE(*,'(A\)')' SYSTEM PRESSURE (PSIA) -->'
      READ(*,*)PR
      WRITE(*,'(A\)')' SYSTEM TEMPERATURE (DEG.F) -->'
      READ(*,*)TR
      WRITE(*,'(A)')' EXPERIMENTAL DEW POINT (PSIA)'
      WRITE(*,'(A)')' IF NOT AVAILABLE, TYPE 0.'
      WRITE(*,'(A\)')' -->'
      READ(*,*)PBEXP
   30 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'            ************************************'
      WRITE(*,*)'            *   DO YOU WANT MULTI-STAGE        *'
      WRITE(*,*)'            *   SEPARATION CALCULATIONS ?      *'
      WRITE(*,*)'            ************************************'
      WRITE(*,*)'            *   (0) NO                         *'
      WRITE(*,*)'            *   (1) YES, 1 STAGE               *'
      WRITE(*,*)'            *   (2) YES, 2 STAGES              *'
      WRITE(*,*)'            *   (3) YES, 3 STAGES              *'
      WRITE(*,*)'            *   (4) YES, 4 STAGES              *'
      WRITE(*,*)'            *   (5) YES, 5 STAGES              *'
      WRITE(*,*)'            ************************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,*)NS
      IF(NS.LT.0.OR.NS.GT.5.) GO TO 30
      IF(NS.GT.0) THEN
      WRITE(*,*)
      WRITE(*,*)' ENTER SEPARATOR PRESSURE (PSIA),TEMPERATURE (DEG.F)'
      WRITE(*,*)
      DO 31 I=1,NS
       WRITE(*,'(A,I1,A\)')' STAGE ',I,' -->'
       READ(*,*)PSEP(I),TSEP(I)
   31 CONTINUE
      ENDIF
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') GO TO 24
    8 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'      ************************************************'
      WRITE(*,*)'      *    EQUILIBRIUM RATIO ESTIMATION              *'
      WRITE(*,*)'      ************************************************'
```

```
      WRITE(*,*)'      *    (1) SUCCESSIVE SUBSTITUTION              *'
      WRITE(*,*)'      *                 OR                          *'
      WRITE(*,*)'      *    (2) ACCELERATED SUCCESSIVE SUBSTITUTION  *'
      WRITE(*,*)'      ********************************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,*)METH
      IF (METH.LT.1.OR.METH.GT.2) GO TO 8
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') GO TO 24
    9 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'          ******************************************'
      WRITE(*,*)'          *   ESTIMATION OF HC-N2 AND HC-CO2       *'
      WRITE(*,*)'          *   BINARY INTERACTION PARAMETERS        *'
      WRITE(*,*)'          ******************************************'
      WRITE(*,*)'          *   (1) GRABOWSKI-DAUBERT CORRELATION    *'
      WRITE(*,*)'          *                OR                      *'
      WRITE(*,*)'          *   (2) LAVAL CORRELATION                *'
      WRITE(*,*)'          ******************************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,*)IBIN
      IF (IBIN.LT.1.OR.IBIN.GT.2) GO TO 9
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') GO TO 24
   10 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'          ******************************************'
      WRITE(*,*)'          *   DO YOU WANT PHASE COMPOSITION FILES ?  *'
      WRITE(*,*)'          ******************************************'
      WRITE(*,*)'          *                (Y) YES                   *'
      WRITE(*,*)'          *                                          *'
      WRITE(*,*)'          *                (N) NO                    *'
      WRITE(*,*)'          ******************************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,'(A)')IPRINT
      IF (IPRINT.NE.'Y'.AND.IPRINT.NE.'N') THEN
      IF (IPRINT.NE.'y'.AND.IPRINT.NE.'n') GO TO 10
      ENDIF
      IF (IPRINT.EQ.'Y'.OR.IPRINT.EQ.'y') THEN
      WRITE(*,*)
      WRITE(*,*)
```

```
      WRITE(*,*)
      WRITE(*,*)'     ***INPUT FILE NAME (USING PC-DOS STANDARD)***'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' NAME OF FILE FOR FLASH PHASE COMPOSITIONS -->'
      READ(*,'(A)')FLSH
      WRITE(*,'(A\)')' NAME OF FILE FOR DIFFERENTIAL PHASE COMPOSITIONS
     *-->'
      READ(*,'(A)')DIFF
      ELSE
      FLSH='NO FILE'
      DIFF='NO FILE'
      ENDIF
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') GO TO 24
   11 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'          ************************'
      WRITE(*,*)'          *       OUTPUT         *'
      WRITE(*,*)'          ************************'
      WRITE(*,*)'          *   (1) TO PRINTER     *'
      WRITE(*,*)'          *         OR           *'
      WRITE(*,*)'          *   (2) TO FILE        *'
      WRITE(*,*)'          ************************'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,*)IOUT
      IF (IOUT.LT.1.OR.IOUT.GT.2) GO TO 11
      IF (IOUT.EQ.2) THEN
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)'     ***INPUT FILE NAME (USING PC-DOS STANDARD)***'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' NAME OF FILE FOR OUTPUT -->'
      READ(*,'(A)')OUTPUT
      ELSE
      OUTPUT='PRN'
      ENDIF
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') GO TO 24
   12 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A)')' ***SUMMARY OF COMPONENT MOLE FRACTION***'
      WRITE(*,*)
      IF (INPUTW.EQ.2) GO TO 14
      WRITE(*,'(A)')'     COMPONENT     LIQUID MOLE   VAPOR MOLE'
```

```
      WRITE(*,'(A)')'                          FRACTION      FRACTION'
      DO 13 I=1,16
        WRITE(*,'(A,I2,2X,A9,6X,F8.6,6X,F8.6)')' ',I,CN(I),X(I),Y(I)
   13 CONTINUE
      WRITE(*,*)
      WRITE(*,'(A\)')' DO YOU WANT TO CHANGE ANY COMPONENT MOLE FRACTION
     * (Y OR N) ? -->'
      READ(*,'(A)')RESP
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') THEN
      WRITE(*,'(A\)')' ENTER LINE NUMBER OF COMPONENT TO BE CHANGED -->'
      READ(*,*)INT
      WRITE(*,'(A)')' ENTER (LIQUID FRACTION, VAPOR FRACTION)'
      WRITE(*,'(A,A,A\)')' ',CN(INT),'  -->'
      READ(*,*)X(INT),Y(INT)
      GO TO 12
      ELSE
      GO TO 16
      ENDIF
   14 WRITE(*,'(A)')'     COMPONENT    MOLE FRACTION'
      DO 15 I=1,16
        WRITE(*,'(A,I2,2X,A9,6X,F8.6)')' ',I,CN(I),Z1(I)
   15 CONTINUE
      WRITE(*,*)
      WRITE(*,'(A\)')' DO YOU WANT TO CHANGE ANY COMPONENT MOLE FRACTION
     * (Y OR N) ? -->'
      READ(*,'(A)')RESP
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') THEN
      WRITE(*,'(A\)')' ENTER LINE NUMBER OF COMPONENT TO BE CHANGED -->'
      READ(*,*)INT
      WRITE(*,'(A)')' ENTER NEW MOLE FRACTION'
      WRITE(*,'(A,A,A\)')' ',CN(INT),'  -->'
      READ(*,*)Z1(INT)
      GO TO 12
      ENDIF
   16 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A)')' ***SUMMARY OF INPUT PARAMETERS***'
      WRITE(*,*)
      WRITE(*,'(A,F8.3)')' (1) MOLECULAR WEIGHT OF LIQUID HEAVY+
     *= ',MWC7
      WRITE(*,'(A,F8.6)')' (2) SPECIFIC GRAVITY OF LIQUID HEAVY+
     *= ',SGC7
      WRITE(*,'(A,F8.3)')' (3) MOLECULAR WEIGHT OF VAPOR HEAVY+
     *= ',GMWC7
      WRITE(*,'(A,F8.6)')' (4) SPECIFIC GRAVITY OF VAPOR HEAVY+
     *= ',SGGC7
      WRITE(*,'(A,F8.6)')' (5) SYSTEM GAS-OIL RATIO (SCF/STB)
     *= ',GOR
      WRITE(*,'(A,F8.2)')' (6) SYSTEM PRESSURE (PSIA)
```

```
     *= ',PR
      WRITE(*,'(A,F8.2)')' (7) SYSTEM TEMPERATURE (DEG.F)
     *= ',TR
      WRITE(*,'(A,F8.2)')' (8) EXPERIMENTAL DEW POINT PRESSURE (PSIA)
     *= ',PBEXP
      WRITE(*,*)
      WRITE(*,'(A\)')' DO YOU WANT TO CHANGE ANY INPUT PARAMETERS (Y OR
     *N) ? -->'
      READ(*,'(A)')RESP
      IF(RESP.EQ.'Y'.OR.RESP.EQ.'y') THEN
      WRITE(*,'(A\)')' ENTER LINE NUMBER OF PARAMETER TO BE CHANGED -->'
      READ(*,*)INT
      GOTO(17,18,19,20,40,21,22,23)INT
   17 WRITE(*,'(A\)')' MOLECULAR WEIGHT OF LIQUID HEAVY+ -->'
      READ(*,*)MWC7
      GO TO 16
   18 WRITE(*,'(A\)')' SPECIFIC GRAVITY OF LIQUID HEAVY+ -->'
      READ(*,*)SGC7
      GO TO 16
   19 WRITE(*,'(A\)')' MOLECULAR WEIGHT OF VAPOR HEAVY+ -->'
      READ(*,*)GMWC7
      GO TO 16
   20 WRITE(*,'(A\)')' SPECIFIC GRAVITY OF VAPOR HEAVY+ -->'
      READ(*,*)SGGC7
      GO TO 16
   40 WRITE(*,'(A\)')' SYSTEM GAS-OIL RATIO (SCF/STB) -->'
      READ(*,*)GOR
      GO TO 16
   21 WRITE(*,'(A\)')' SYSTEM PRESSURE (PSIA) -->'
      READ(*,*)PR
      GO TO 16
   22 WRITE(*,'(A\)')' SYSTEM TEMPERATURE (DEG.F) -->'
      READ(*,*)TR
      GO TO 16
   23 WRITE(*,'(A\)')' EXPERIMENTAL DEW POINT PRESSURE (PSIA) -->'
      READ(*,*)PBEXP
      GO TO 16
      ENDIF
   24 WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)' ***SUMMARY OF COMPUTATIONAL PARAMETERS***'
      WRITE(*,*)
      WRITE(*,'(A,I1,A)')'  [1]   MULTI-STAGE SEPARATION CALCULATIONS:
     *',NS,' STAGE'
      IF(NS.GT.0) THEN
      WRITE(*,*)'       PRESSURE   TEMPERATURE'
      DO 33 I=1,NS
      WRITE(*,'(9X,F6.1,7X,F5.1)')PSEP(I),TSEP(I)
   33 CONTINUE
```

```
      ENDIF
      WRITE(*,*)
      WRITE(*,'(A,I1)')'  [2]   EQUILIBRIUM RATIO ESTIMATION:-->',METH
      WRITE(*,*)'        (1) SUCCESSIVE SUBSTITUTION'
      WRITE(*,*)'        (2) ACCELERATED SUCCESSIVE SUBSTITUTION'
      WRITE(*,*)
      WRITE(*,*)' [3]   ESTIMATION OF HC-N2 AND HC-CO2       '
      WRITE(*,'(A,I1)')'        BINARY INTERACTION PARAMETERS:-->',IBIN
      WRITE(*,*)'        (1) GRABOWSKI-DAUBERT CORRELATION    '
      WRITE(*,*)'        (2) LAVAL CORRELATION                '
      WRITE(*,*)
      WRITE(*,*)' [4]   PHASE COMPOSITION FILES'
      WRITE(*,'(A,A)')'        FLASH PHASE COMPOSITION:-->',FLSH
      WRITE(*,'(A,A)')'        DIFFERENTIAL PHASE COMPOSITION:-->',DIFF
      WRITE(*,*)
      IF (IOUT.EQ.1) THEN
      WRITE(*,'(A)')'  [5]   OUTPUT:-->PRINTER'
      ELSE
      WRITE(*,'(A,A)')'  [5]   OUTPUT:-->',OUTPUT
      ENDIF
      WRITE(*,*)
      WRITE(*,'(A\)')' DO YOU WANT TO CHANGE ANY COMPUTATIONAL PARAMETER
     *S (Y OR N) ? -->'
      READ(*,'(A)')RESP
      IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') THEN
      WRITE(*,'(A\)')' ENTER LINE NUMBER OF PARAMETER TO BE CHANGED -->'
      READ(*,*)INT
      GOTO(30,8,9,10,11)INT
      ENDIF
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)' ************************************************************
     ********'
      WRITE(*,*)' ************************************************************
     ********'
      WRITE(*,*)' **   DO YOU WANT TO SAVE INPUT DATA IN A FILE (Y OR N)
     * ?   **'
      WRITE(*,*)' ************************************************************
     ********'
      WRITE(*,*)' ************************************************************
     ********'
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,*)
      WRITE(*,'(A\)')' -->'
      READ(*,'(A)')RESP
```

```
 IF (RESP.EQ.'Y'.OR.RESP.EQ.'y') THEN
 WRITE(*,'(A\)') ' NAME OF INPUT FILE (USING PC-DOS STANDARD) -->'
 READ(*,'(A)')INFILE
 OPEN(9,FILE=INFILE,STATUS='NEW')
 WRITE(9,*)INPUTW,(X(I),Y(I),Z1(I),I=1,16),MWC7,SGC7,GMWC7,
*SGGC7,GOR,PR,TR,PBEXP,METH,IBIN,IOUT
 WRITE(9,'(4A)')FLSH,DIFF,OUTPUT,IPRINT
 WRITE(9,*)NS
 IF (NS.GT.0) THEN
 WRITE(9,*)(PSEP(I),TSEP(I),I=1,NS)
 ENDIF
 ENDIF
 CLOSE (9)
 POEXP=PBEXP
 RETURN
 END
```

```
      SUBROUTINE EXDATA
C
C     PURPOSE : STORE DATA FOR PVT ANLYSIS AND FOR EXAMPLE CALCULATIONS.
C
      COMMON/D1/CN(16)
      COMMON/D2/MW(16),MVOL(16)
      COMMON/D3/W(16),PC(16),TC(16)
      COMMON/D9/D(16,16),IBIN,TB(16)
      COMMON/DAT3/CN3(12),CPT3(6),CZ3(12)
      COMMON/DAT6/CN6(10),CPT6(6),CZ6(10)
      COMMON/DAT7/CN7(12),CPT7(6),CZ7(12)
      REAL MVOL,MW
      CHARACTER*9 CN
      CN(1)='N2'
      CN(2)='H2S'
      CN(3)='CO2'
      CN(4)='METHANE'
      CN(5)='ETHANE'
      CN(6)='PROPANE'
      CN(7)='I-BUTANE'
      CN(8)='N-BUTANE'
      CN(9)='I-PENTANE'
      CN(10)='N-PENTANE'
      CN(11)='HEXANES'
      CN(12)='HEPTANES'
      CN(13)='OCTANES'
      CN(14)='NONANES'
      CN(15)='DECANES'
      CN(16)='HEAVY+'
      MW(1)=28.013
      MW(2)=34.076
      MW(3)=44.01
      MW(4)=16.043
      MW(5)=30.07
      MW(6)=44.097
      MW(7)=58.124
      MW(8)=58.124
      MW(9)=72.151
      MW(10)=72.151
      MW(11)=86.178
      MW(12)=100.125
      MW(13)=114.232
      MW(14)=128.259
      MW(15)=142.286
      MW(16)=0.0
      MVOL(1)=.5561
      MVOL(2)=.8529
      MVOL(3)=.6911
      MVOL(4)=.8555
      MVOL(5)=1.3528
```

```
MVOL(6)=1.3929
MVOL(7)=1.655
MVOL(8)=1.5948
MVOL(9)=1.8515
MVOL(10)=1.8328
MVOL(11)=2.0814
MVOL(12)=2.3341
MVOL(13)=2.5921
MVOL(14)=2.85
MVOL(15)=3.1067
MVOL(16)=0.0
W(1)=.04
W(2)=.1
W(3)=.225
W(4)=.0104
W(5)=.0986
W(6)=.1524
W(7)=.1848
W(8)=.201
W(9)=.2223
W(10)=.2539
W(11)=.3007
W(12)=.3498
W(13)=.3942
W(14)=.4455
W(15)=.4885
W(16)=.375
PC(1)=493.024
PC(2)=1306.17
PC(3)=1071.17
PC(4)=667.8
PC(5)=707.8
PC(6)=616.3
PC(7)=529.1
PC(8)=550.7
PC(9)=490.4
PC(10)=488.6
PC(11)=436.9
PC(12)=396.8
PC(13)=360.6
PC(14)=332.
PC(15)=304.
PC(16)=396.8
TC(1)=-232.424
TC(2)=212.717
TC(3)=87.923
TC(4)=-116.63
TC(5)=90.09
TC(6)=206.01
TC(7)=274.98
```

```
      TC(8)=305.65
      TC(9)=369.1
      TC(10)=385.7
      TC(11)=453.7
      TC(12)=512.8
      TC(13)=564.22
      TC(14)=610.68
      TC(15)=652.1
      TC(16)=512.8
      TB(1)=139.27
      TB(2)=383.066
      TB(3)=350.37
      TB(4)=201.
      TB(5)=332.21
      TB(6)=416.02
      TB(7)=470.59
      TB(8)=490.79
      TB(9)=541.81
      TB(10)=556.61
      TB(11)=615.41
      TB(12)=668.86
      TB(13)=717.91
      TB(14)=763.16
      TB(15)=805.17
      TB(16)=0.0
      END
0
```

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VITA

Thomas Nathan Tufts was born in New Orleans, Louisiana on September 28, 1956, the son of James David and Ruth Mary Tufts. After graduation from John F. Kennedy High School, New Orleans, Louisiana, he attended flight school at Sowell Aviation, Panama City, Florida. He received his commercial, instrument, flight instructor, and instrument instructor ratings. After flight school he instructed commercial and instrument students at Professional Aviation Inc., Beaumont, Texas. Aspiring for more academic education, he moved to Hammond, Louisiana, to pursue a part-time education, while instructing flight students at Hammond Aviation. Ambitious with his academic studies in chemistry, he transferred to Louisiana State University at Baton Rouge to complete his Bachelor of Science degree. As a student at Louisiana State University, he worked part-time instructing introductory chemistry laboratory classes. In August 1982, he entered graduate school in petroleum engineering at The University of Texas at Austin.